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Field Evaluation of Cathodic Protection Systems Using Ceramic-Coated Anodes for Lock and Dam Gates

by
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This study documented the use and evaluated the field performance of impressed current cathodic protection systems using ceramic-coated anodes made of a new material (titanium-based iridium oxide), for miter, sector, and tainter gate applications in Army Civil Works (water resource) projects. A cost analysis including materials, installation, and power consumption was done, and the new system was compared to conventional HSCBCI anode systems.

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13. ABSTRACT (Maximum 200 words)

Since 1950, the Army Corps of Engineers has used impressed current cathodic protection (CP) systems, using either graphite or high silicon chromium bearing cast iron (HSCBCI) anodes with protective coatings. Both systems help control corrosion of hydraulic structures immersed in either fresh or salt waters, and hybrid CP systems can contain both types of anodes. Research continues in the search for better and more economical materials.

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FOREWORD

This study was conducted for the Electrical and Mechanical Branch, Engineering Division, Directorate of Civil Works, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Civil Works Investigations and Studies (CWIS) Work Unit 31204, "Corrosion Mitigation in Civil Works Projects." The technical monitor was John Gilson, CECW-EE.

This research was performed by the Engineering and Materials Division (FM), of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Ashok Kumar. Dr. Paul Howdyshell is Chief, CECER-FM. Dr. David M. Joncich is Acting Chief, CECER-FL. Appendixes A, K and M were authored by Jim Bushman, Corrpro Companies, Inc, Medina, Ohio. Appendixes C, D, E, F, G, H, I, J, and L were authored by Phil Chitty, Ceranode Technologies, APS Materials, Inc., Dayton, Ohio. The USACERL technical editor was William J. Wolfe, Information Management Office.

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1 INTRODUCTION

Background

The U.S. Army Corps of Engineers (USACE) has used cathodic protection (CP) in combination with protective coatings for the corrosion mitigation of hydraulic structures immersed in either fresh or salt water. Protective coatings are rarely 100 percent effective. They contain pinholes, scratches, and connected porosity even on application. As the coatings degrade with time, these imperfections, known as "holidays," have a pronounced effect on overall coating integrity because of underfilm corrosion.

In addition to its use with protective coatings, cathodic protection has been an effective way to control corrosion. Cathodic protection systems consist of anodes that pass a protective current to the structure, and a power source that provides the electrical potential and the current. There are two types of cathodic protection systems: sacrificial, and impressed current. Sacrificial anodes such as magnesium or zinc alloy are made of metals that corrode (wear) more readily than the structure because of their lower electrochemical potential. These anodes do not require an outside power source, and consequently need very little maintenance. Anodes are replaced when the anode material is consumed. Impressed current type anodes are made of a durable material that suffers little electrochemical wear or dissolution, but rather supplies the protective current provided by the rectifier. All impressed current anodes require routine maintenance since the system involves many electrical connections. Hybrid cathodic protection systems installed on structures can contain both types of anodes to provide the protective current.

Since 1950, USACE has used impressed current cathodic protection systems with graphite or high silicon chromium bearing cast iron (HSCBCI) anodes. The first systems were installed on the Mississippi River near Rock Island, IL on an experimental basis. Since then, cathodic protection systems have been used widely. About 22 cathodic protection systems were installed and are currently functioning on structures on the Tennessee-Tombigbee Waterway, Alabama River, and Black Warrior River in the Mobile District (Greene and Bushman 1991). Cathodic protection systems have been used successfully on the Intercoastal Waterway on seven sector gates in Florida (Jacksonville District) and on miter gates in Louisiana (New Orleans District). Impressed current systems have also been installed on three lock gates located on the Columbia River in the northwest United States. Similarly, impressed current systems using both graphite and HSCBCI anodes were installed on lock gates on the Ohio River during the 1970s. However, damage from ice and debris has made most of these systems inoperable.

HSCBCI anodes are made by a casting process and are generally brittle in nature, resulting in a product that cannot be easily machined or welded. In addition, strict quality control is required to avoid the formation of microcracks in the anode during casting and transportation. HSCBCI anodes inherently have a very low fracture toughness and due to fabrication limitations, are formed in simple cylindrical or button shapes. The electrical connection between the HSCBCI anode and the electrical cable is made mechanically, and caulking compounds are required to seal the connection. The anode-to-wire connection has been the cause of past anode failures, reducing the durability of the HSCBCI anodes used in cathodic protection systems for lock gate applications (Greene and Bushman 1991).

Failure of the anode-to-wire connections and damage from ice and debris are major causes of malfunction in cathodic protection systems (Greene and Bushman 1991). The traditional 6-in. diameter

HSCBCI button anode weighs about 18 lb, and requires a metallic bolt for support.* The bolt is electrically isolated from the anode by surrounding it with plastic bushings and by injecting epoxy through filling ports. Strict quality control is required in field applications to prevent electrical shorting of the anode to the structure (Figure 1).

The use of precious metal-coated, titanium-based anode materials has increased and has captured a larger share of the cathodic protection market for off-shore structures, water tanks, and underground storage tanks. Precious metal anodes consist of a coating of electrically conductive platinum or platinum oxide with a thickness of approximately 0.005 in. and an extremely low electrochemical dissolution rate (0.01 gm per ampere year). Table 1 shows the dissolution rates for various anode materials.

Since the early 1980s, a new type of ceramic-coated composite anode material has been used for various electrochemical processes, particularly in the electrolytic production of chlorine and cathodic protection systems including off-shore, water tank, and groundbed applications. The mixed metal oxide (MMO) ceramic-coated anodes consist of a conductive coating of iridium or ruthenium oxide (IrO_2 and RuO_2, respectively) applied by thermal decomposition onto specially prepared titanium substrates. The coatings are applied by spraying aqueous metallic salts onto the titanium substrates and then heating them to several hundred degrees Celsius. Multiple layers of coating material may be applied by the process to provide a maximum coating thickness of approximately 1 mil. The ceramic and HSCBCI systems need to be systematically compared to determine whether one type can offer the advantage of better performance or lower cost.

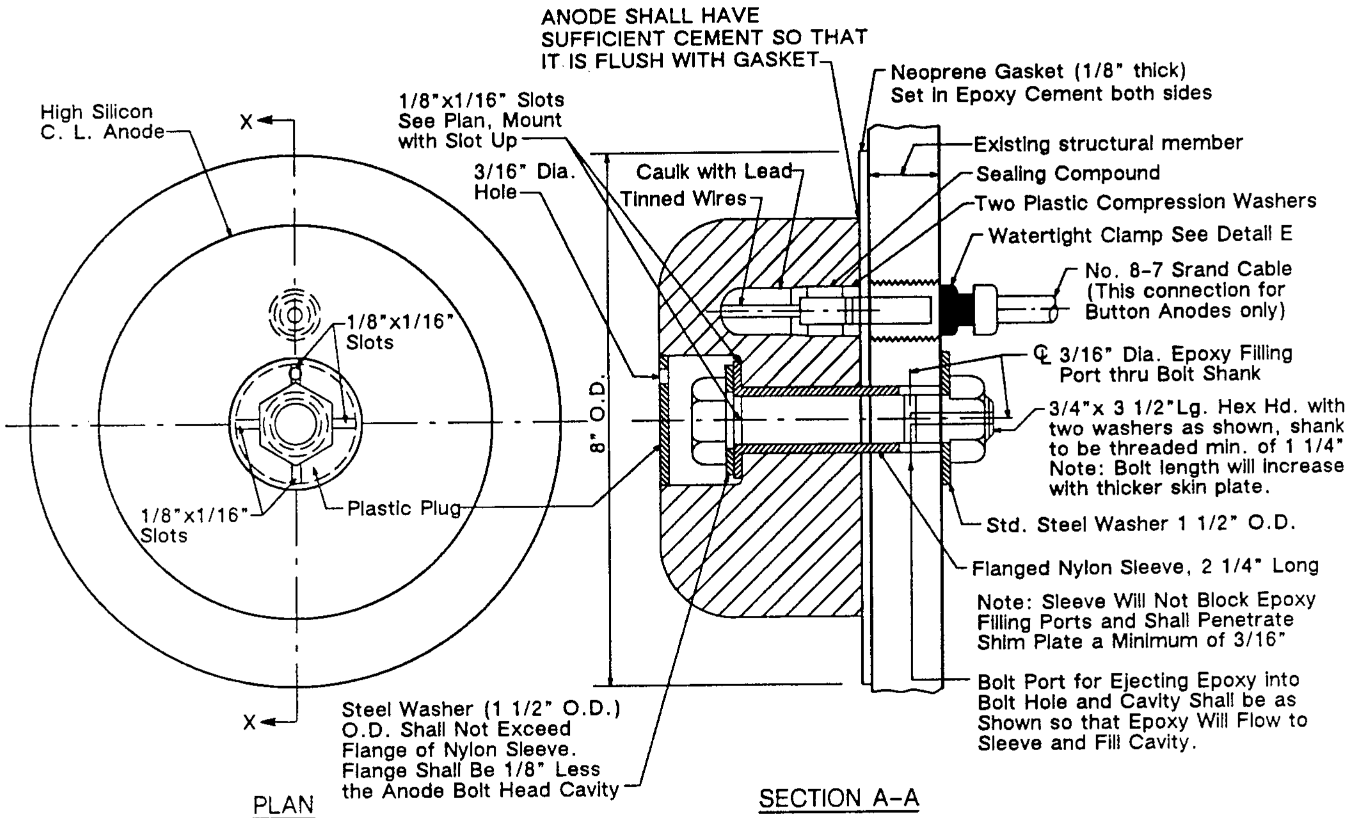
Objective

The objective of this study was to document the designs used and to evaluate the field performance of impressed current cathodic protection systems using titanium-based iridium oxide ceramic-coated anodes for miter, sector, and tainter gate applications in Army Civil Works (water resource) projects. Additional objectives were to do a cost analysis including power consumption, and to compare the use of titanium-based iridium oxide ceramic-coated anodes to conventional HSCBCI anode systems.

Approach

Ceramic-coated anodes were developed for potential use in Army Civil Works (water resource) projects. Impressed current systems were designed using mixed metal oxide (ceramic) coated anodes. Special disk and rod configurations containing self-healing anode-to-wire connections were designed and fabricated. Draft procurement specifications, documenting the designs, were developed and provided to the USACE Pittsburgh District (Pike Island), Nashville District (Cordell Hull), and Jacksonville District (Cape Canaveral). The impressed current systems were installed by the in-house staff at the above locations. The structures protected were a miter gate at Pike Island, a tainter gate at Cordell Hull, and a sector gate at Cape Canaveral. The field evaluation of the CP systems included potential surveys, power consumption tests, and durability studies.

* A metric conversion table is provided on p 31.



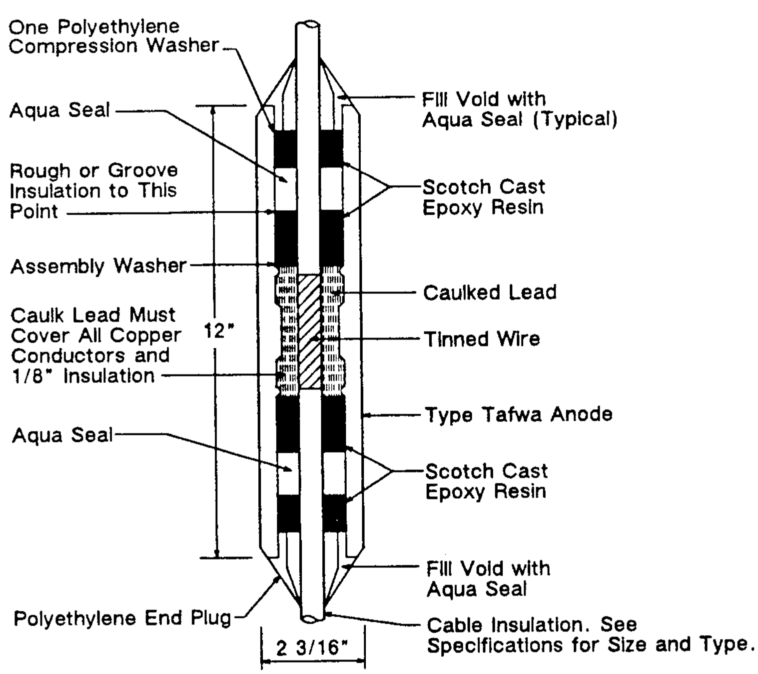


Figure 1. HSCBCI "Sausage" and "Button" Anode Designs.

Table 1

Impressed Current Anode Materials and Their Dissolution Rates

Anode Material	Anode Dissolution Rate (g/amp-yr)
High Silicon Cast Iron (HSCBCI)	450
Graphite	200
Cast Magnetite	40
Lead Silver Alloy (1.5 percent Silver)	30
Plasma Sprayed Lithium Ferrite	1.7
Sintered Nickel Ferrite	1.6
Platinum-Coated Titanium	0.01
IrO_2/TiO_2 (wear rate in fresh water)	0.006
RuO_2/TiO_2 (wear rate in salt water)	0.001

Mode of Technology Transfer

The technology contained in this report will be used in updating Corps of Engineers Guide Specifications, CW 16643, "Cathodic Protection Systems (Impressed Current) for Lock Miter Gates" (Headquarters, U.S. Army Corps of Engineers [HQUSACE], 19 August 1991).

2 CATHODIC PROTECTION DESIGNS FOR NAVIGATION LOCK AND DAM GATES USING CERAMIC-COATED ANODES

Ceramic-Coated Anode Properties and Configurations

Ceramic-coated anodes consist of an electrically conductive mixed metal oxide (MMO) coating deposited onto a titanium metal substrate. The advantages of fabricating anodes from these materials are their very low resistivity (10^{-5} to 10^{-6} ohm-cm) and their very low dissolution (wear) rate. Schrieber and Mussinelli (1986) list wear rate values of 6 mg/A-yr in chloride deficient (fresh) waters, at an anode current density of 13.9 A/sq ft, and 0.5 to 1.0 mg/A-yr in seawater or brine at an anode current density of 55.7 A/sq ft. Table 1 lists the dissolution rates of these anode materials. The hardness of the mixed metal oxide ceramic coating is approximately 6 on the Mohs hardness scale. Appendix A lists detailed cathodic protection design procedures for Pike Island Auxiliary Lock Gate and Appendix B for specifications for ceramic coated anodes. The detailed steps for design of impressed current cathodic protection systems using ceramic anodes are described in ETL 1110-9-10.

The first recorded use of mixed metal oxide ceramic-coated anodes in a cathodic protection application was a seawater installation, in Italy in 1971, where a deep groundbed filled with a bentonite backfill was installed. (Citation to be provided for final publication.) The first cathodic protection application of record in the United States was the use of a single 1 x 39-in. tubular titanium-based MMO ceramic-coated anode with a seawater type ruthenium oxide coating, in an open hole test groundbed near Port Lavaca, TX. This anode was installed in May 1984, and operated at about 9.0 amps until May 1989, when it was removed from the groundbed after approximately 402,000 amp-hrs of operation. Six closed hole groundbeds (with carbonaceous backfill) using tubular mixed metal oxide ceramic anodes were installed near Medford, OK in August 1984, and are still operating at essentially the same circuit resistance as when installed. These were the first ceramic-coated anode groundbeds used in the United States. There are over 4000 tubular MMO groundbeds currently in use in the United States, operating with very few reported failures (Faita, 1988).

To circumvent typical installation concerns, ceramic-coated flat-disk anodes (Life-Saver Anodes) were developed. These anodes consist of an MMO ceramic film deposited onto a 5-in. diameter titanium disk substrate. The anodes are lightweight, weighing approximately 1-lb, and easily installed on most Civil Works structures. The coated substrate is backed with an 11.8-in. diameter protective polyurethane disk that lessens the susceptibility to mechanical damage by acting as a cushion. The backing shield also improves the distribution of current from the anode to the protected structure, and minimizes the possibility of blistering of the coating or paint, which may result from hydrogen gas evolution at the cathode. This can occur if the polarized potential of the structure exceeds -1.20 volts referenced to a $Cu/CuSO_4$ half-cell. In addition, these anodes have factory-made, self-healing electrical connections with a series of waterproof seals designed to eliminate problems with anode shorting and electrical connection failure, and to allow for underwater installation. Figure 2 shows a typical ceramic-coated flat-disk anode. Table 2 presents typical Life-Saver Anode design details.

Rod-type anodes are similar to the flat-disk anodes except that the MMO ceramic coating is deposited onto a 4-ft long titanium rod having male/female connectors to allow for a variety of usable lengths. Because of its lightweight design, a 19.7-ft long rod assembly weighs only 1.2-lb, and can be suspended vertically without the possibility of electrical connection failure. It should be noted that ceramic-coated anode assemblies over 30 ft in total length, used in fresh water applications, must use copper-cored titanium substrates consisting of 40 percent titanium and 60 percent copper (core). The reason for this is that the effective resistance of the anode assembly should not be greater than 10 percent

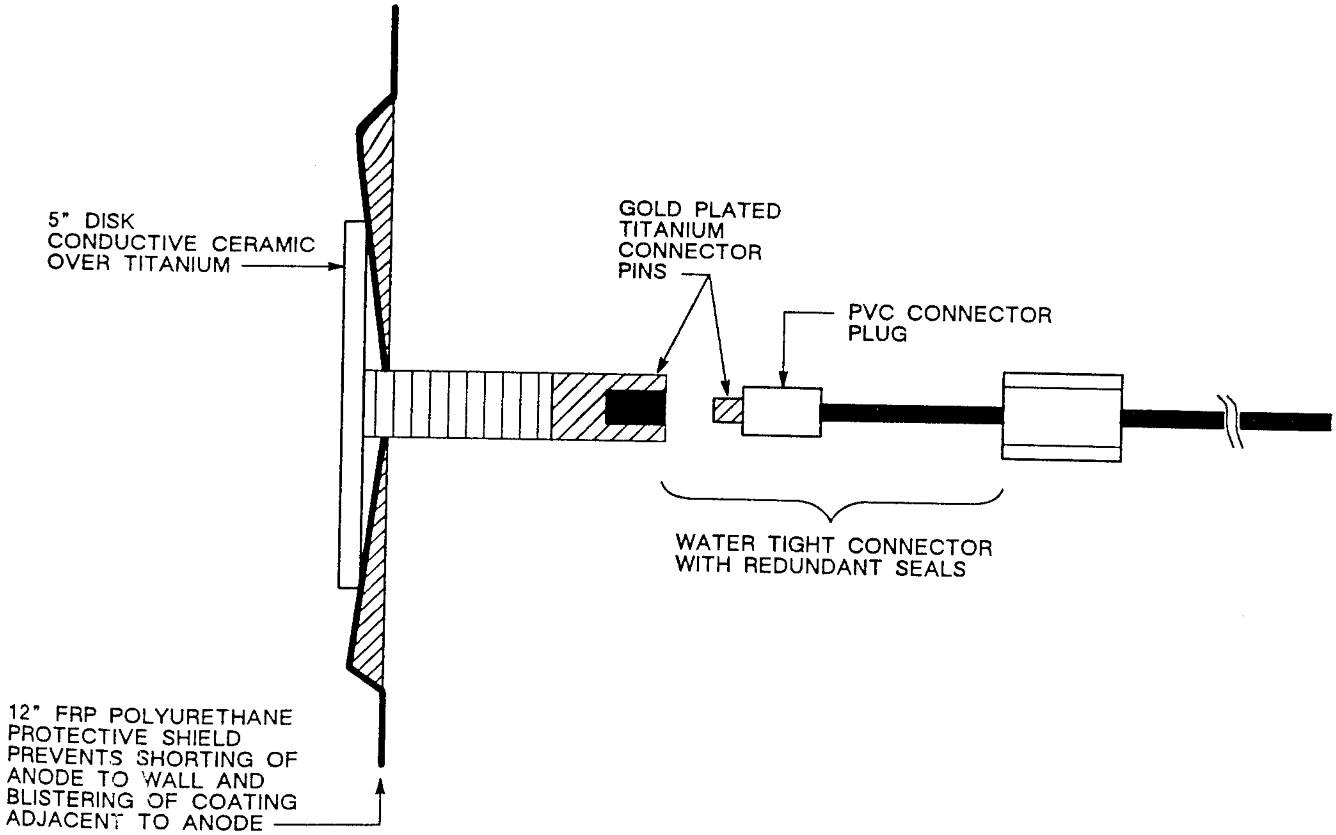


Figure 2. Typical Ceramic-Coated Flat Disk Anode.

Table 2

Life-Saver Anode Design Information

Current Capacity Anode Life	Fresh Water	Brackish Water	Salt Water
20 years	0.8 A	3.1 A	5.5 A
15 years	1.0 A	3.4 A	6.0 A
10 years	1.2 A	4.0 A	7.2 A

NOTES:

1. Much higher currents are possible but the ampere-year specification decreases in a slightly nonlinear fashion as the current is increased. In fresh waters, it is usually not possible to use the full current capacity because of anode resistance.
2. Active surface area is approximately 20.15-sq in.
3. Suggested operating voltages: 20 volts maximum in both fresh and salt water.

of the anode-to-electrolyte resistance. The result would be a disproportionate amount of current generated near the top of the anode and not enough current discharged near the bottom of the anode.

The resistance of a solid titanium rod is approximately 0.01325 ohm/ft compared to the resistance of a copper-cored rod, which has a resistance of 0.00085 ohm/ft. Therefore, a 30-ft length of solid titanium rod would have a total resistance of approximately 0.41 ohm compared to a 30-ft length of copper-cored rod, which would have a total resistance of approximately 0.026 ohm. Figure 3 shows a typical Expand-A-Rod. Table 3 contains typical Expand-A-Rod Anode design information. Ceramic-coated iridium oxide anodes can also be procured in the continuous rod or wire form of 0.0625 to 0.75-in. diameter.

Lock and Dam Designs

For demonstration and evaluation purposes, site-specific complete cathodic protection systems using ceramic-coated anodes were designed according to the plans and specifications contained in Appendix A and installed on the auxiliary lock miter gate at Pike Island Lock and Dam, WV (Figures 4 and 5), a tainter gate at Cordell Hull Dam, TN (Figure 6), and a sector gate at Canaveral Lock, FL (Figure 7).

Pike Island Navigation Lock Miter Gate Design

In designing the cathodic protection system for the navigation lock miter gate at Pike Island, the water resistivity, immersed area of the miter gate, percentage of uncoated or poorly coated metal (coating efficiency), and gate geometry directly determined the number and location of anodes necessary to completely protect the gate.

On the skin side of the miter gate leaf (the side without structural members), flat ceramic-coated disk anodes were used to protect all immersed metal areas except the beveled quoin and miter compartments of the gate. In these areas, rod anode strings were used (Figure 5). To prevent galvanic corrosion caused by dissimilar metals (uncoated stainless steel in contact with carbon steel) near the bottom sill area of the gate seal, an additional number is required in this area. The anodes placed near the sill are typically spaced at one-half the distance of the centrally located anodes. Anodes are generally spaced no more than

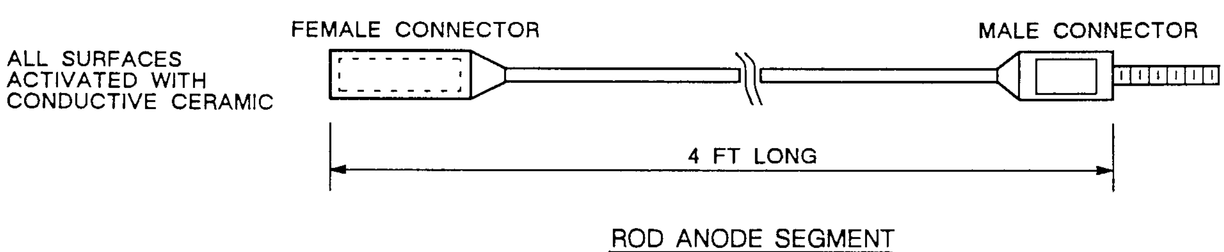


Figure 3. Typical Ceramic-Coated Rod Anode Design.

Table 3

Expand-A-Rod Anode Design Information

Anode Rod Length (cm)	Current Rating in Amperes (20-Year Life) Ceramic: Fresh Water	Sea Water	Brackish Water	Coke Backfill	Ceramic-Coated Material
61	1.1	2.8	1.6	0.9	Solid Ti
22	2.2	5.6	3.3	1.8	Solid Ti
83	3.3	8.4	4.9	2.7	Solid Ti
44	4.4	11.2	6.6	3.6	Solid Ti

NOTES:

1. Connector material is conductive ceramic-coated Ti unless niobium is specified for the copper core rods.
2. Internal rod resistance: solid Ti = 0.01325 ohm/m; copper core = 0.258 ohm/m.
3. Copper/niobium/titanium should be used for salt water as well as long anode strings in fresh water to keep attenuation below 10 percent or where higher breakdown voltages are required (100 volt maximum).
4. Copper core rods have 40 percent valve metal by volume
5. Rods are typically 0.138-in. in diameter. Connectors are typically 0.25-in. in diameter.
6. Current ratings assume no greater than 10 percent attenuation along the total rod length.

10 ft apart in fresh water applications to ensure that current is distributed uniformly without causing paint blistering.

The compartment side of a miter gate is cathodically protected by a number of rod anode strings suspended vertically in the electrolyte. The length of the main anode string is approximately equal to the height difference between normal water level and the bottom seal of the gate (Figure 5). The electrical connection is made above the upper pool level to ensure its electrical integrity. At least one anode string is suspended in each column of compartments through holes cut in the horizontal structural girders because there is not much spillover of current from one compartment to another when the coating is waterlogged. This is necessary to ensure that all of the metallic surface area in each compartment is cathodically protected. In addition, all holes cut in the girders must have a plastic sleeve installed to ensure that the rod anode strings do not contact the structure; otherwise, too much current will be drawn by the girder, which would be very near the anode. This isolation assures uniform current distribution.

Cordell Hull Tainter Gate Design

Cathodic protection system designs used for the Cordell Hull tainter gate are similar to those used on the skin side of the miter gate at Pike Island. The disk anodes had to be bent slightly to follow a slight curvature in the gate contours (Figure 6).

Cape Canaveral Navigation Lock Sector Gate Design

The navigation lock sector gates at Cape Canaveral were protected in much the same way as the Pike Island lock miter gate. (The skin side of the gate is protected by disk anodes while the compartment side is protected by rod anode strings.) The one major difference in designing a cathodic protection system for a sector gate arises from the "pie-shaped" arrangement of the structural compartments (Figure 7). Each column of compartments requires a rod anode string similar to the cathodic protection design used for lock miter gates.

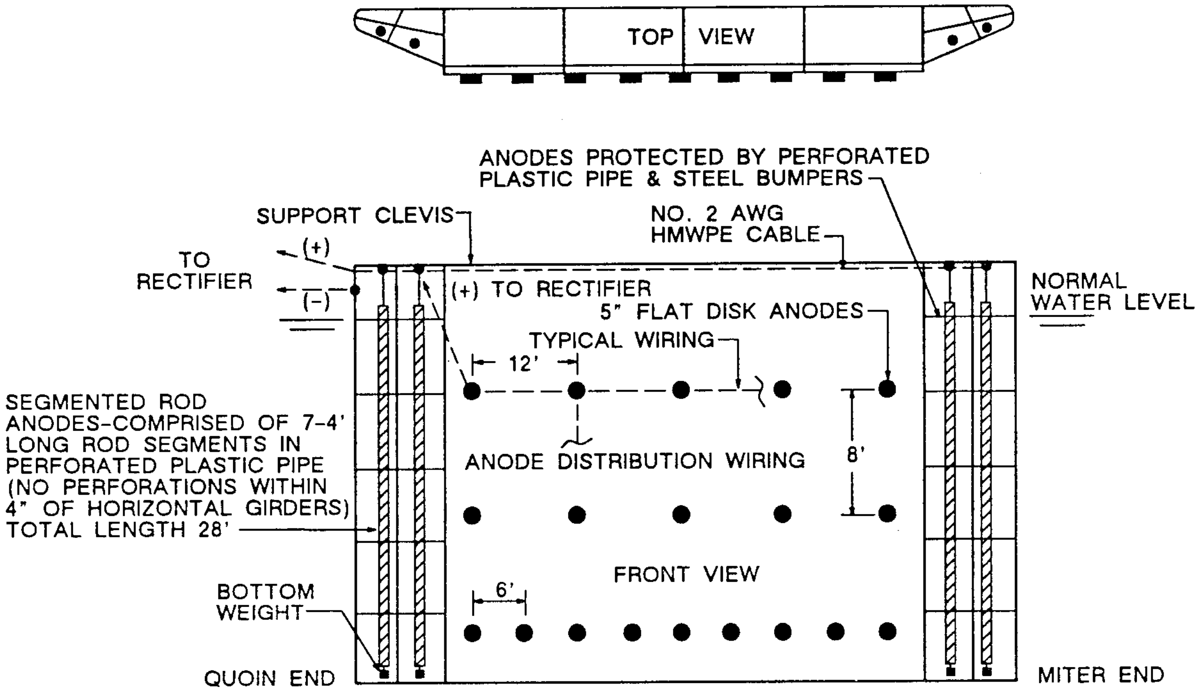


Figure 4. Auxiliary Lock Miter Gate Design at Pike Island.

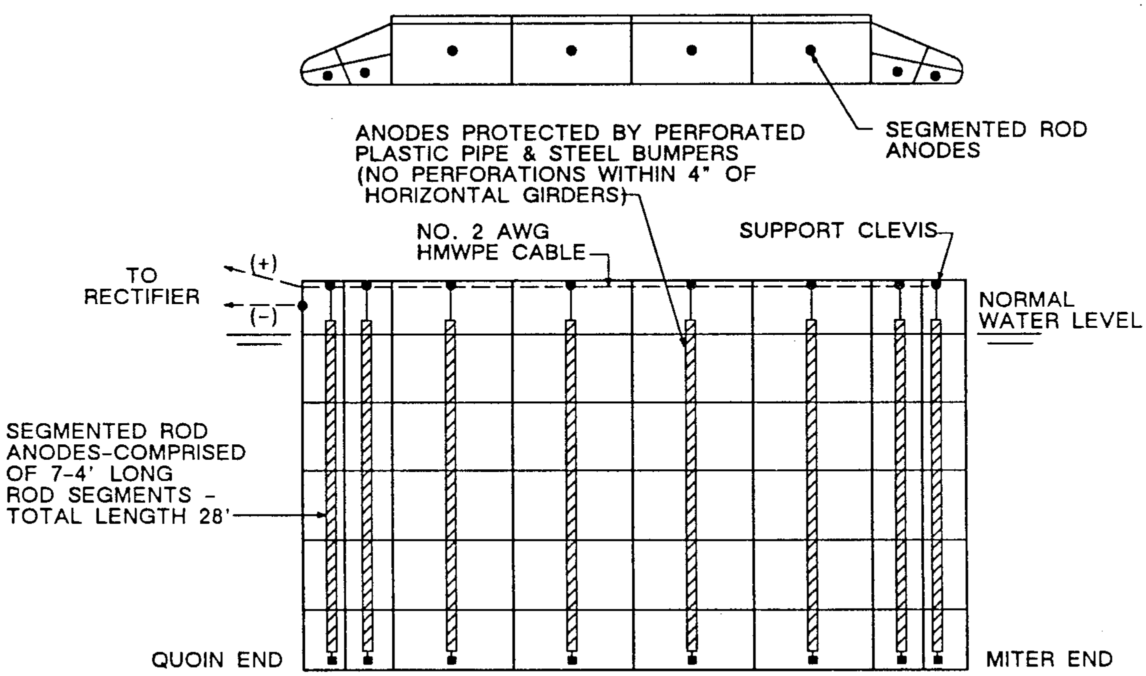


Figure 5. Auxiliary Lock Miter Gate at Pike Island Showing Rod Anode Placement.

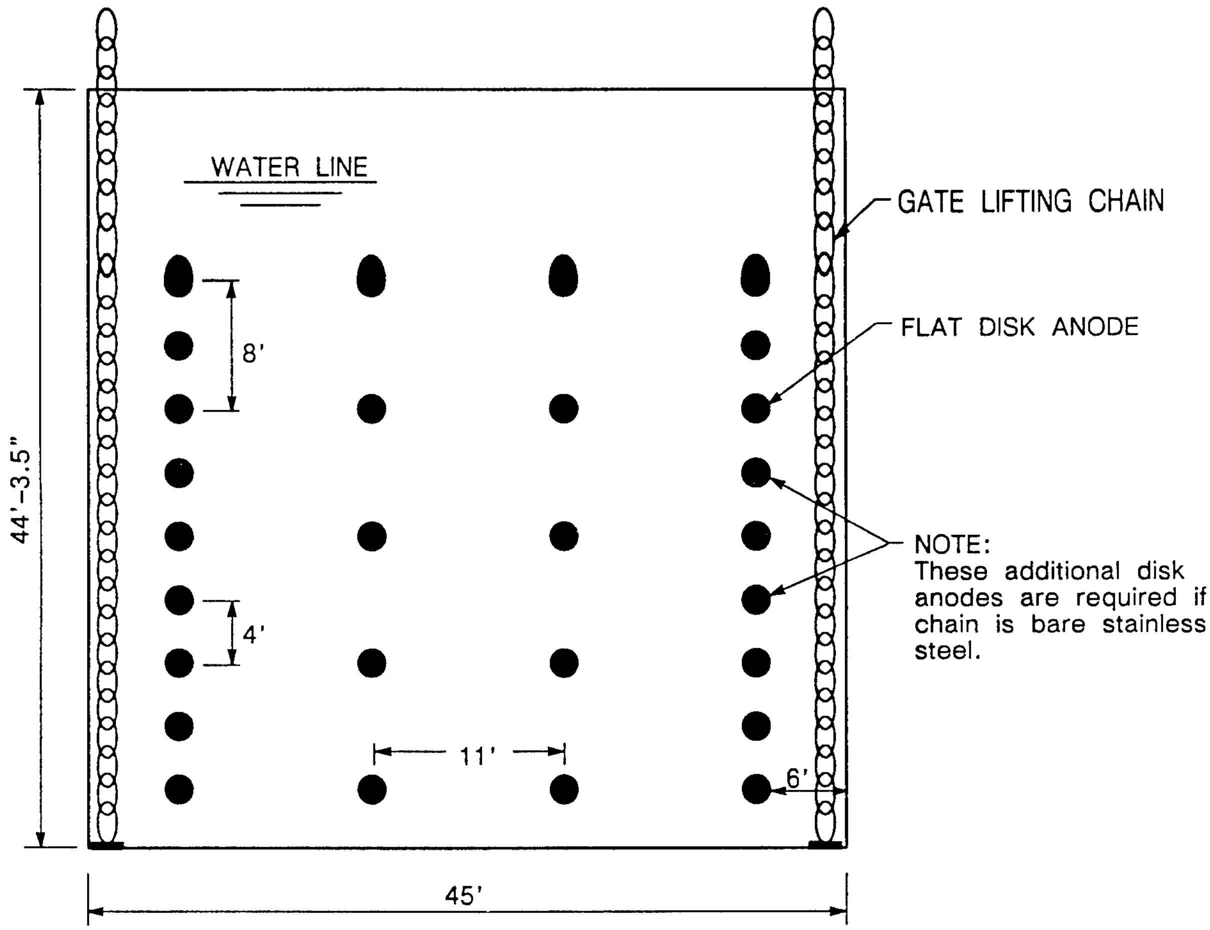


Figure 6. Tainter Gate Design at Cordell Hull Showing Flat Disk Anode Placement.

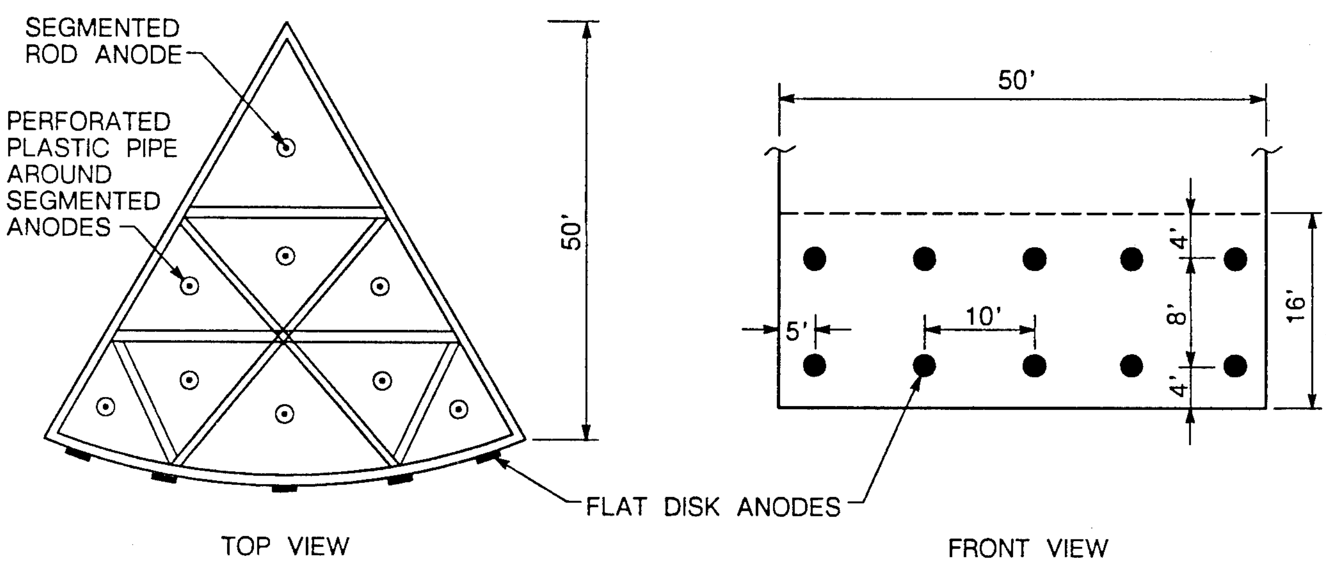


Figure 7. Sector Gate Design at Cape Canaveral Showing Flat Disk Anode Placement.

3 CRITERIA FOR FIELD ASSESSMENT OF CATHODIC PROTECTION SYSTEMS

Basics of Potential Changes

To understand the criteria for cathodic protection, it is critical to understand the changes that occur in the electrical potential of a structure when the protective current is applied to it. Husock (1979) explains:

> It should be noted that cathodic protection when properly applied produces a change in the potential of a structure with respect to reference electrode placed in the soil in proximity to that structure. The cathodic protection current makes the potential thus measured more negative than the potential was before the current was applied, and the amount of change produced is a measure of the effectiveness of the cathodic protection at that location.

Figure 8 shows the changes in electrical potential of the structure (with respect to a $Cu/CuSO_4$ reference half-cell) that occur when the cathodic protection current is applied. Before current is applied, the structure is at its original or "native" potential. When the current is applied, there is a change in potential in the negative direction the instant the current is turned on. As the current is continuously applied over an extended period of time, the potential tends to increase negatively because of polarization. According to Husock (1979), "polarization of a structure is a phenomenon which occurs over a long time period and a structure may not be entirely polarized even after the cathodic protection system has been in operation for many months." If the current is interrupted after the structure has polarized, the potential becomes less negative at the instant of turn-off. The potential then begins to decay, or depolarize, back to the original or native potential.

National Association of Corrosion Engineers CP Criteria

For cathodic protection criteria, corrosion engineers typically use two Recommended Practices (RPs) published by the National Association of Corrosion Engineers (NACE): RP-01-69 (1992 Revision), "Control of External Corrosion on Underground or Submerged Metallic Piping Systems," and RP-02-85, "Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems." Although there are some differences in the wording of the two Recommended Practices due to the different structures that each describes, the content is essentially the same (Appendix A).

The current NACE criteria also state that the IR drop shall be considered when measurements are interpreted. Figure 8 shows the region of the potential as a function of time curve, which is considered to be the IR drop. Since the NACE criteria refer to two IR drops, the soil/electrolyte IR drop and the metal ohmic IR drop, any attempt to measure the structure-to-soil potential must take these IR drops into account. Sometimes this can be achieved by placing the reference half-cell immediately adjacent to the structure, and sometimes, by measuring the potential instantaneously after the cathodic protection current is interrupted ("instant off potential").

Discussion of the NACE Criteria for Cathodic Protection

Structures

The NACE criteria were developed for the corrosion protection of underground gas pipes, so their values represent the complete corrosion mitigation of steel. The -0.85-volt criterion (as referenced to

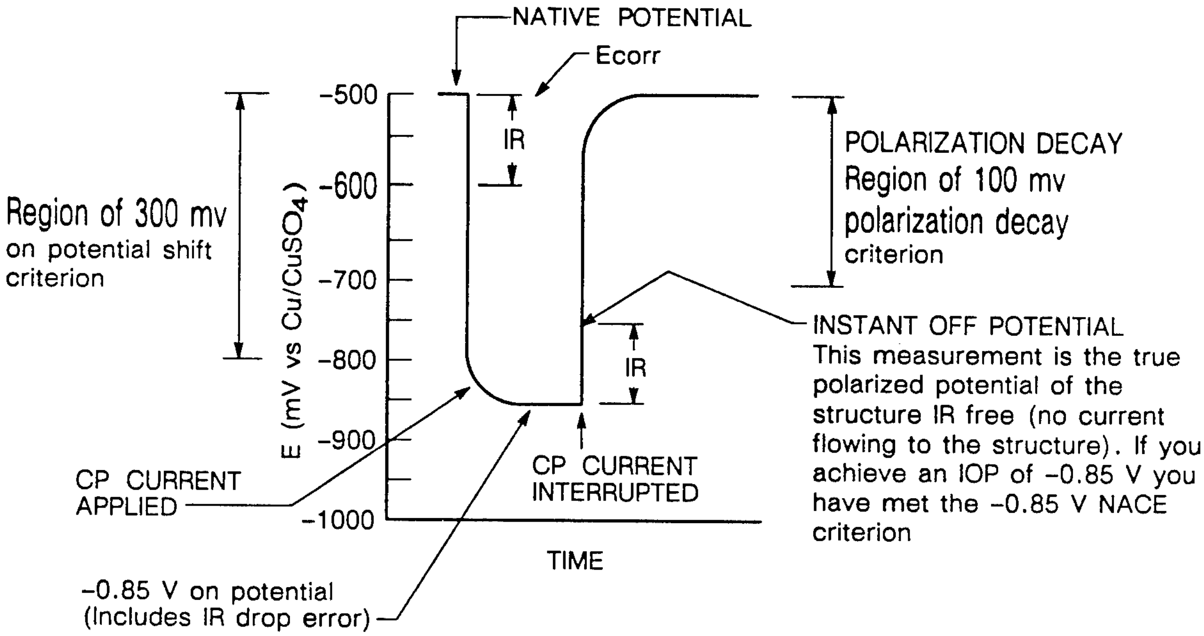


Figure 8. Potential and Potential Shift Criteria for Cathodic Protection of Steel.

$Cu/CuSO_4$) is the most conservative criterion of all. Because voltage gradients and voltage drops resulting from the line currents in the coated pipeline are often negligible, the -0.85 volt criterion is well suited for use on coated structures. The IR drops referred to are not usually significant and the original native (static) potentials are often more negative than -0.5 volts. Therefore, a -0.85-volt level is readily obtainable on coated structures with a reasonable level of cathodic protection current, without much risk of coating damage.

On a bare or poorly coated structure, a -0.85 volt criterion may not be required, and in fact, may be an excessive and wasteful use of cathodic protection current and power. The excessive requirement imposed by the -0.85 volt criterion is especially true on older bare structures that have native potentials much less negative than -0.5 volt, sometimes approaching -0.3 volt (as referenced to $Cu/CuSO_4$).

In relatively deaerated environments, the polarization E log I curve often exhibits linear (Tafel) behavior with increased test current (Figure 9). A straight line is usually drawn tangentially to the Tafel portion of the curve and extended towards the ordinate. From this Tafel extension, a wide number of interpretations are commonly drawn. The most common interpretation of the E log I curve is that the required current to achieve complete protection is that point where the tangent to the Tafel slope breaks away from the data. This occurs at a current of approximately 100 mA (Figure 9).

The validity of the E log I criterion depends on obtaining this linear (Tafel) behavior, which most often occurs on structures exposed to deaerated environments where the corrosion cell kinetics are governed by activation polarization. Tafel behavior is not to be expected for structures exposed to aerated environments because the corrosion cell kinetics are controlled by concentration polarization (e.g., the diffusion of oxygen to the cathodic sites where reduction occurs). At lock and dam structures, most of the metallic surface area is considered to be exposed to a deaerated environment, although Tafel behavior is not frequently observed. Nevertheless, E log I criteria have been used by corrosion engineers in freshwater (Greene and Bushman 1991).

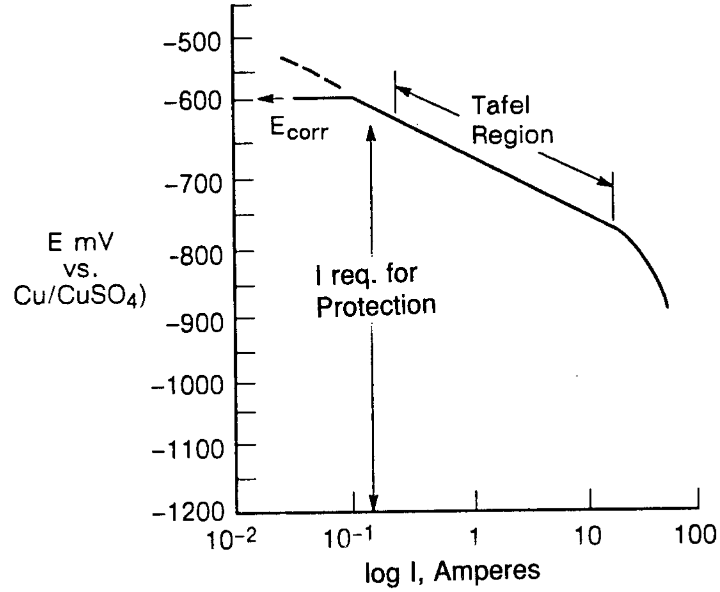


Figure 9. E Log I Polarization Curve Showing Tafel Behavior.

For steel structures in freshwater where localized corrosion damage is not critical (as is the case with gas pipes), and where prolonging the structural life by a factor of two is desired, the amount of polarization current and the required potential shift may be reduced. This will also reduce the power costs and lower the risk of paint blistering. Based on field experience, it has been proposed that an ON potential of -0.800 mV may be sufficient for corrosion mitigation of painted lock and dam steel structures immersed in fresh water (Greene and Bushman 1991). Similarly, a polarization decay of only 80 mV, as compared to the NACE RP-01-69 criteria of 100 mV decay, may be sufficient for lock and dam structures in fresh water.

Recommended Sequence for Cathodic Protection System Survey

According to Greene and Bushman (1991), the recommended sequence for a CP system potential survey is:

1. Inspect the physical condition of the system

2. Inspect the rectifier and perform a preliminary potential survey, recording the "as found" values

3. Confirm the readings using a voltmeter and ammeter

4. Measure the anode outputs at the junction box

5. Adjust the rectifier DC voltage or current and anode outputs at the junction box

6. Allow the readings to stabilize at least 4 hours for well coated structures; more for older, waterlogged coatings

7. Conduct a detailed potential survey and record the values.

In the preliminary test, potential measurements are conducted in the most likely high and low polarization buildup locations. The highest polarization is near the anode and the lowest polarization is farthest from the anode locations (near large bare steel regions). The rectifier and the junction box are adjusted to bring the potential at the farthest location to meet the selected criteria without increasing the potential at the nearest location to more than -1.2 volt (Instant Off Potential [IOP] value) to avoid any paint damage due to blistering. Sometimes a compromise is reached between the highest and lowest polarization buildup. After adjusting the rectifier and the junction box, the structure is allowed to stabilize. It may take a few hours or a few days for the new polarization buildup to equilibrate. Well coated structures may stabilize in 4 to 6 hours and old waterlogged coatings may take a few days. After adjustment and stabilization, a detailed survey is conducted to record potential values at regular intervals on a grid pattern.

4 POTENTIAL SURVEY RESULTS

Potential Survey Instrumentation

Potential surveys were conducted by qualified contractors in 1989 and 1990. For the fresh water measurements at Pike Island and Cordell Hull, a Fluke Model 75 digital voltmeter (DVM) with an 11 megohm input resistance was used to read the potential difference between the cathodically protected structure and a reference half-cell. This $Cu/CuSO_4$ reference half-cell was a Harco Permacell, Model IHRP-801 with a ± 5 mV stability.* For the salt water measurements at Cape Canaveral, the same Fluke Model 75 DVM was used in conjunction with a Harco Permacell, Model IHRP-803 Ag/AgCl reference half-cell. To keep the potential readings consistent in the appendices, 71 mV was added to the readings measured with the Ag/AgCl half-cell. This 71 mV value is a conversion factor between the Ag/AgCl half-cell readings and $Cu/CuSO_4$ half-cell readings.

Native Potential Data

The native potential data represents the average native potentials of the gate structure with no cathodic protection on, with respect to a reference half-cell such as $Cu/CuSO_4$.

ON Potential Data

The ON potential values are the potentials of the structure (cathode) with the CP current on. It is not an "IR free" reading and includes IR drops in the electrolyte and does not represent a true polarized potential at the structure.

IOP Data

The IOP measurements are taken with zero current flowing to the structure from the anode, shown as the minimum (flat portion) of the rectified sinusoidal waveform. This can be accomplished by using a Xetron CP Analyzer or a Wave Form Analyzer (WAFA). These specialized instruments are commercially available with electronic circuitry. The instant off potential data can also be obtained with an oscilloscope.

OFF Potential Data

The OFF potential was measured with a DVM to compare its value with the IOP value. The Off potential values are lower down on the decay curve since the measurements are made a second or two after the CP current is interrupted, as shown in Figure 8. This allows time for the structure to depolarize, making the observed readings slightly lower than the IOP.

During the 1991 surveys, the IOPs were measured using a Xetron Model 730 Cathodic Protection Analyzer. These values were compared to measurements taken with a Leader LCD-100 Digital Storage Oscilloscope in conjunction with the appropriate voltage offset circuitry to provide a 4 mV resolution, to verify that current was not flowing to the structure during measurement.** All potential readings contained in Appendices B through I are negative numbers as referenced to either a $Cu/CuSO_4$ or Ag/AgCl reference half-cell, even though the signs have been omitted for simplification. The potentials recorded in the ON columns were measured with the DVM and a reference half-cell with the rectifiers on, with no

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*Fluke, PO Box C9090, Everett, WA 98206; Harco, 1365 Wiley Rd, Suite 145, Schaumberg, IL 60173.

**Xetron Corp., 40 West Crescentville Rd., Cincinnati, OH 45246.

compensation for IR drop due to the reference half-cell location relative to the structure. The potentials recorded in the OFF columns were measured with the second reading of the update of the DVM after the rectifier current had been interrupted.

Pike Island Auxiliary Navigation Lock

A rehabilitation of the auxiliary lock miter gates at Pike Island was conducted in August 1986. It should be noted that the auxiliary lock gates at Pike Island were not repainted during the lock rehabilitation (neither were the main lock gates). The existing paint is over 20 years old and appears to be in good condition, although it is waterlogged. Only those areas where the paint had been destroyed due to structure modification during rehabilitation were repainted. The Pike Island miter gate design (Figures 4 and 5) was used for the upstream gate/downstream side of the river wall (USG/DSS/RW). To compare cost and alternative system designs, the other three leaves had the following modifications to the original design (Figure 5):

1. Four strings of rod anodes were installed in the center section on the compartment side of the gates, instead of eight for the USG/DSS/RW.

2. The rod anode strings were not divided as with the USG/DSS/RW where the bottom two compartment anodes of each rod string had separate leads. This design of using two separate leads for each column allows for current output flexibility by independently controlling the current flowing to the stainless steel seal area near the bottom.

3. Slots, instead of holes, were used on the USG/DSS perforated polyvinyl chloride (PVC) protection tubes because of ease of machining.

4. Commercially available, two circuit rectifiers with fixed voltage taps were used instead of the four circuit, constant voltage/constant current rectifiers that were used on the USG/DSS/RW, due to ease in procurement. They were "off-the-shelf" items with short procurement lead time.

After dewatering, significant galvanic corrosion was observed under the gate near the stainless steel seal, due to the presence of dissimilar metals. Therefore, several magnesium anodes were added on the downstream side (under the gates) in 1986. This was necessary because it was not possible to alter the existing design of the ceramic-coated anode system by installing additional anodes. (The design for the main lock rehabilitation at Pike Island implemented in August 1988 included ceramic-coated disk anodes under the gate for this purpose). The potential survey data (Appendix C) show that the addition of the magnesium anodes had little effect on the overall polarized potential values of the structure at this time. However, with additional coating degradation, these magnesium anodes will still protect the steel near the sill.

During August 1989, 747 potential values (ON, OFF, and polarization DECAY) were measured over the surface of the gates including the quoins and miters (Appendix C). Note that the recorded data for the upstream sides of the miter gates at Pike Island starts at the sill (bottom) and continues up in 3-ft intervals until the surface upper pool level is reached. The OFF potential data shows that 97 percent of the points meet the -0.85 volt criteria, and 99 percent meet the 100 mV shift/decay criteria. The total power required for protection of all four gates is 2600 watts, as measured on the secondary side of the rectifier.

1991 Repair Made to CP System at Pike Island

Prior to discussing the potential survey data taken on 15 February 1991 and 12 June 1991, it is necessary to describe a repair made to the perforated PVC pipe and steel half shell support pipe that housed the anode. A wooden log became trapped between the lock wall and the upstream surface of the USG near the quion end of the miter gate when it was opened. This broke the perforated PVC pipe and bent its associated steel half-shell support, located next to the quoin of the upstream gate/upstream side/island wall (USG/USS/IW). The repair was made on 12 June 1991. The ceramic-coated titanium rod anodes did not need to be replaced, and were reinstalled in the new flexible polyethylene (PE) pipe. The following is a description of the repair procedure:

1. The existing rod anode string was pulled up.

2. The broken section of 3-in. diameter PVC perforated pipe was removed.

3. The damaged section of 4-in. diameter steel half shell pipe was removed with a cutting torch.

4. The remaining PVC pipe was again supported with appropriate clamps.

5. The junction box was rewelded to the gate at the top of pipe.

6. Paint was applied to the freshly welded and torch-cut areas.

7. The length of the 2-in. diameter perforated PE pipe required to replace the broken PVC section, was determined. It extended far enough into the remaining PVC pipe so that if it were flexed it would not pull out of the pipe. PE pipe was chosen because of its excellent elongation characteristics.

8. 1-in. diameter holes were drilled on 1.5-in. centers on 3 sides, 90 degrees apart in the pipe, except for the portion that fit into the remaining PVC pipe. NOTE: If the PE pipe passes through the bulkhead, holes would not be drilled for 6-in. above and 6-in. below the bulkhead.

9. The 2-in. diameter perforated PE pipe was installed so that it extended several feet into the 3-in. diameter PVC pipe. The blank side of the PE pipe (the side without holes) was installed facing towards the back of the compartment.

10. The PE pipe was anchored at the top by means of a 1-in. diameter steel pipe, perpendicular through the PE pipe. This is located inside the junction box at the top of pipe after it passes through the last bulkhead. The length of the bar was sized to just fit the width of the junction box. (If necessary, the newly installed PE pipe can now be replaced from the top where it is anchored.)

11. Perforations in the portion of PE pipe inserted inside the PVC pipe were drilled through existing holes so that new and old holes were aligned.

12. All of the original ceramic-coated anodes were reused for replacement.

13. The operation of the CP system was verified by potential measurements.

The durability of the ceramic-coated titanium rod anodes was demonstrated at Pike Island when the steel bumper pipe was bent by a log, but the anode rod remained undamaged and continued to provide protection. This anode was reused after repair was made to the protective pipe.

The IOP data contained in Appendix D for both the 15 February 1991 and 12 June 1991 surveys indicates that in all cases, either one or both of the following NACE criteria were met or exceeded: (1) a negative cathodic voltage of at least 0.85 volts as measured between the structure surface and a $Cu/CuSO_4$ reference half-cell, and (2) a minimum negative polarization voltage decay/buildup of 100 mV. By meeting a -0.85 volt IOP, the -0.85 volt NACE criteria have been more than satisfied since the IR drop was considered in the readings. All of the IOP readings meet the 100 mV polarization decay criteria, when the native potential values are subtracted from the polarized IOP values at the same position on the grid (Figure 8).

More than 750 potential values (ON, OFF, and IOP) were measured on the lock gate surface, including the quoins and miters. The rectifier data in Appendix D shows an increase in the anode current for both the rod strings and disk anodes from 15 February 1991 to 12 June 1991 before adjustment. The measured anode current for circuit no. 1 (rod anode strings) was 10.24 amp on 15 February 1991, and increased to 31 amp on 12 June 1991 before adjustment. This represents a 202 percent increase in the anode current. The current for the disk anodes increased from 0.18 amp on 15 February 1991 to 0.48 amp on 12 June 1991. This represents a 167 percent increase in anode current, with an average IOP value of -1.20 volts measured for the gate face on 12 June 1991 before adjustment. Note that a major portion of the increase in the average IOP was primarily due to the increase in the rod anode current of circuit no. 1.

Factors such as temperature, environmental pH, cathode surface area (related to coating condition), electrolyte resistivity, and degree of aeration can affect the anode current required for complete cathodic protection. Increasing temperature tends to depolarize the structure because of the increased diffusion rate of the reducible species to the cathodic sites. Subsequently, the rate of the reduction reaction is increased. Figure 10 shows this relationship, where E_{cp} is the polarized cathodic potential, $E_{c,oc}$ is the native cathodic potential, $E_{a,oc}$ is the native anodic potential, and I_{req} is the current required for protection. The numerical subscripts represent the two different temperature regimes. The slope of the low temperature regime line shows that, in low temperature conditions, changes in temperature have little effect on the current requirements. Conversely, the slope of the high temperature regime line shows that, for high temperature conditions, the required current is greatly affected by changes in temperature. When the rate of the reduction reactions increase, the level of polarization decreases, increasing the current required for protection. As a result, more current is needed to polarize a structure in the summer, when temperatures are higher, than in the winter (NACE 1986). Therefore, the 167 percent increase in anode current from February 1991 to June 1991 can be explained by the increase in the water temperature.

Cordell Hull Tainter Gate

Ceramic-coated disk anodes were mounted at the locations shown in Figure 6, and the individual leads were brought to the junction box. With this design, the current passing through each anode can be conveniently monitored at this junction box. The anodes are divided into circuits in the junction box and proceed to a constant current rectifier. Circuit no. 1 powers the eight anodes located alongside the chains (zone 1), and circuit no. 2 powers the seven anodes located along the sill and the anode in the north corner. Circuit no. 3 powers the rest of the anodes. There is no ceramic-coated anode on the south corner; instead a small magnesium block anode was placed there. Figure 6 shows the layout of the 26 ceramic disk anodes, which corresponds to the data contained in Appendices E and F.

The data was gathered on three different testing dates: the NATIVE potentials were taken during May 1988 (Appendix E), and the ON and OFF potential measurements were made on 25 August 1989 (Appendix F) and 4 March 1991 (Appendix G). The NATIVE and OFF potential data tabulated in 1988 for the Cordell Hull tainter gate is contained in Appendix E.

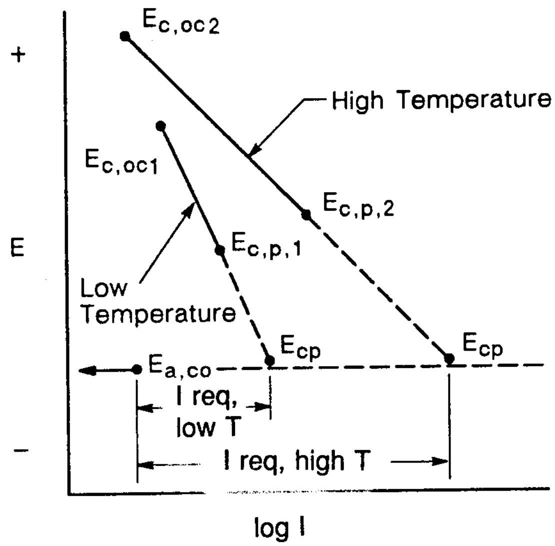

Figure 10. Effect of Temperature on Current Required for Complete Cathodic Protection.

The 1989 IOP data contained in Appendix F demonstrates that the entire tainter gate at Cordell Hull meets either the 100 mV polarization decay/shift criteria and/or the -0.85 volt criteria. Measurements taken at the terminal box shunts indicate that all anodes are functioning except for one disk anode (no. 23). This anode was not operational because it had been disconnected during maintenance of the gate and was never reconnected. Appendix F also contains an actual polarization decay chart. The particular point used to record data for the decay chart was located at the center of the gate between two anodes, and registered a decay shift of 244 mV after 6 hours.

The Cordell Hull CP system continues to function effectively, as shown by the March 1991 potential survey data. This CP system has now been in operation for over 4 years. The IR corrected IOP data contained in Appendix G indicates that essentially the entire tainter gate at Cordell Hull meets either the –0.85 volt criteria and/or the 100 mV shift criteria. The only exceptions are a 97 mV decay reading at the sill area and a 79 mV decay reading at location 1 (15-ft. depth). This is because anode no. 23 was never reconnected. The rectifier is operating efficiently, requiring only 40 W of power to protect the structure.

Cape Canaveral Lock Sector Gates

The system at this site required less mechanical protection than at any of the other sites because of the lack of icing conditions and debris. Disk anodes were used on the skin plate and rod anodes were used to protect the web area. Ten disk anodes were mounted on the skin side of each of the four sector gates. Nine strings, 8-ft in length, each with a total weight of 3 lb, were hung in the web area. The ceramic-coated rod anodes were considerably easier to install than the sacrificial, 250-lb zinc anodes that were previously used.

Since there was going to be a period of approximately 6 months before the impressed current system could be energized, a few sacrificial zinc anodes were installed to cathodically protect the sector gate in the interim. This later proved to be a hinderance during initial adjustment of the impressed current system as these anodes interfered with the gate potential measurements. The system was readjusted in August 1988 after the zinc anodes had been removed. Since there are concerns of overprotection even at levels slightly more negative than -0.85 volt in a salt water environment, care was taken to set the system lower than -0.85 volt with respect to $Cu/CuSO_4$. The zoned system, designed with constant current rectifiers, provided the flexibility needed to completely protect the structure. The system was tested and re-adjusted over a period from 27-29 August 1989. All parts of the gate meet the NACE criteria of 100 mV decay (Appendix H).

During the potential survey on 25 February 1991, the CP system needed some maintenance because one of the Life-Saver Anodes was not functioning. Analysis by a Corps diver (confirmed by the diver under contract) at the time of the survey, revealed that the anode cable had been accidently clamped under the compression cap during the underwater installation 4 years ago. The diver replaced the connector cable, restoring anode operation. The design of the underwater cable connection on the Life-Saver Anode allows for this type of simple maintenance.

During the February 1991 survey, it was also discovered that four of the 10-turn current control adjustments on the gate 3 rectifier were not functioning. This meant that either the rectifier control bridge or the potentiometer for those four circuits was bad. Replacement parts were not available, so the four LSA disk anodes continued to operate at a 40 percent reduction in power. The reduced power to these anodes appeared to have little affect on the overall gate potential readings since current distribution is excellent in salt water. The rectifier was repaired in June 1991 by replacing the control bridge and connecting it to a winding on the other transformer. All of the rectifiers were updated with fuses in the control circuits to prevent the transformers from burning out in case the control bridges were to short out.

As mentioned above, the potential survey was conducted after the anode current was reduced about 40 percent. The potential survey data contained in Appendix I indicates that a further reduction in the anode current was required due to polarization buildup. The potentials should be around -0.780 v (referenced to a Ag/AgCl half-cell) as compared to their present values, which are in the range of -0.950 to -0.999 v. In June 1991, after the rectifier repair, the current was reduced and another survey was taken. The results are contained in Appendix J.

5 COST ANALYSIS AND DISCUSSION OF CERAMIC ANODE AS COMPARED TO HSCBCI ANODE

This chapter presents a comparison of power consumption, durability, and installed costs of ceramic anodes and HSCBCI cathodic protection systems for lock and dam gates.

Power Consumption Comparison Between Ceramic-Coated and HSCBCI

Anodes

The power consumption P is given by:

$$P = I^2 R_T \qquad \text{[Eq 1]}$$

where I is the total protective current through the cathodic protection circuit, and R_T is the total resistance of the circuit.

Current requirements can be calculated based on coating efficiency and current density (current per square foot). The efficiency of the coating will have a direct effect on the total current requirement, as Equation 2 shows:

$$I = A\,I\,(1.0 - CE) \qquad \text{[Eq 2]}$$

where I is total protective current, A is total structure surface area (sq ft), I is required current density, and CE is coating efficiency.

Coating efficiency is directly affected by the type and age of coating used and by quality control during coating application. Coating efficiency can vary from 1.0 for freshly painted surfaces to 0.0 for bare steel. For newly painted surfaces, the current required for cathodic protection is infinitely small. The importance of coating efficiency is evident in the fact that a bare structure may require 100,000 times as much current as would the same structure if well coated and new. Waterlogged and aged coatings can require current densities as high as 6 mA/sq ft.

Table 4 summarizes the annual cathodic protection power costs for a ceramic-coated anode system and an equivalent HSCBCI anode system. The detailed calculations are shown in Appendix M. Table 4 and Figure 11 show that, for a coating efficiency of 50 percent, the annual power cost for the ceramic-coated system is 17 percent lower than for an equivalent CP system using HSCBCI anodes. However, at a coating efficiency of 95 percent, the power cost is slightly higher (1.6 percent) for the ceramic-coated anode system than for an equivalent HSCBCI system.

Ceranode Technologies* performed an anode power consumption test that compared a ceramic-coated disk anode and HSCBCI button anode. Both of these anodes were alternately installed on a 12-ft x 12-ft painted steel plate raft in fresh water, with concentric bare metal circular stripes simulating holidays. Appendix L contains the results of this test. These results show that the power consumed by the ceramic-coated disk anode was 1.07 W as compared to 1.25 W for the K6 HSCBCI 2 button anode. To achieve a 100 mV polarization decay at a 5-ft radius, mark from the center of the anode. The ceramic-

* Ceranode, Division of APS Technology, 153 Walbrook Ave, Dayton, OH 45405.

Table 4

Summary of Annual Cathodic Protection Power Costs for HSCBCI Anode System and Ceramic-Coated Anode System

	HSCBCI Anode Option			Ceramic-Coated Titanium Anode Option		
Gate Surface	**95% Coated**	**80% Coated**	**50% Coated**	**95% Coated**	**80% Coated**	**50% Coated**
USG/US Skinplate	$ 0.34	$ 3.26	$ 17.63	$ 0.57	$ 6.33	$ 36.11
USG/US Chambers	$ 0.15	$ 1.05	$ 4.88	$ 0.16	$ 0.84	$ 3.12
USG/DS Sillplate	$ 0.05	$ 0.42	$ 2.16	$ 0.08	$ 0.82	$ 4.51
USG/DS Chambers	$ 1.90	$ 20.26	$ 113.83	$ 1.55	$ 11.83	$ 58.03
DSG/US Skinplate	$ 0.45	$ 4.35	$ 23.61	$ 0.71	$ 8.52	$ 49.64
DSG/US Chambers	$ 0.18	$ 1.25	$ 5.74	$ 0.20	$ 1.04	$ 3.86
DSG/DS Sillplate	$ 0.05	$ 0.42	$ 2.16	$ 0.08	$ 0.82	$ 4.51
DSG/DS Chambers	$ 1.07	$ 10.89	$ 60.27	$ 0.91	$ 6.69	$ 31.82
Total power cost for each alternative	**$ 4.19**	**$ 41.90**	**$ 230.28**	**$ 4.26**	**$ 36.89**	**$ 191.60**

Notes:
1. See Appendix M for detailed calculations.
2. Power costs were calculated using an electric utility rate of $ 0.07/kWH.
3. Power requirements included calculation of anode-to-cathode back emf, anode-to-electrolyte resistance, anode lead wire resistance and resistance to current flow through the anode plastic pipe protector holes for those anodes so equipped.
4. Cathode (structure) resistance was not included in the calculation since it was considered negligible and equal for both alternatives.
5. The variation in relative power cost is due to the slightly higher anode-to-cathode back emf for the ceramic anode material as compared to the HSCBCI material.
6. For coatings that have a 90 percent or lower efficiency, the ceramic anode design considered in the study will have the lowest power cost. For higher coating efficiencies, the HSCBCI anode material will have a slightly lower (but negligible) power cost.

coated disk anode had a slightly lower power consumption as compared to the HSCBCI button for the same coating efficiency.

Installed Cost Comparison

Table 5 contains the cost estimates for each alternative anode material and corresponding installation labor. (Appendix M contains detailed estimates.) Cost estimates were computed for both the upstream and downstream surfaces of the upper and lower gate leafs. For the HSCBCI anode system, the costs were based on the specifications contained in Corps of Engineer Guide Specification CW 16643, "Cathodic Protection Systems (Impressed Current) For Lock Miter Gates." For the ceramic-coated anode CP system, the costs were based on the Pike Island auxiliary lock Plans and Specifications.

The total cost of the HSCBCI anode system (button and strings) is $253,329.13. The total cost of a typical ceramic-coated anode system (LSA disks and Expand-A-Rod strings) is $257,006.75. The total cost of the alternate ceramic-coated anode system (LSA disks and continuous titanium wire) is $235,948.69. The difference in cost between the HSCBCI and ceramic-coated anode systems is based partially on the labor costs involved in installing the anodes for the CP systems (Table 5). The difference in system cost between the two ceramic-coated anode systems (Expand-A-Rod versus the continuous wire) is based on the anode material cost (Appendix M). Both ceramic-coated anode systems (rod and wire) can be installed and maintained by nonspecialized, in-house staff.

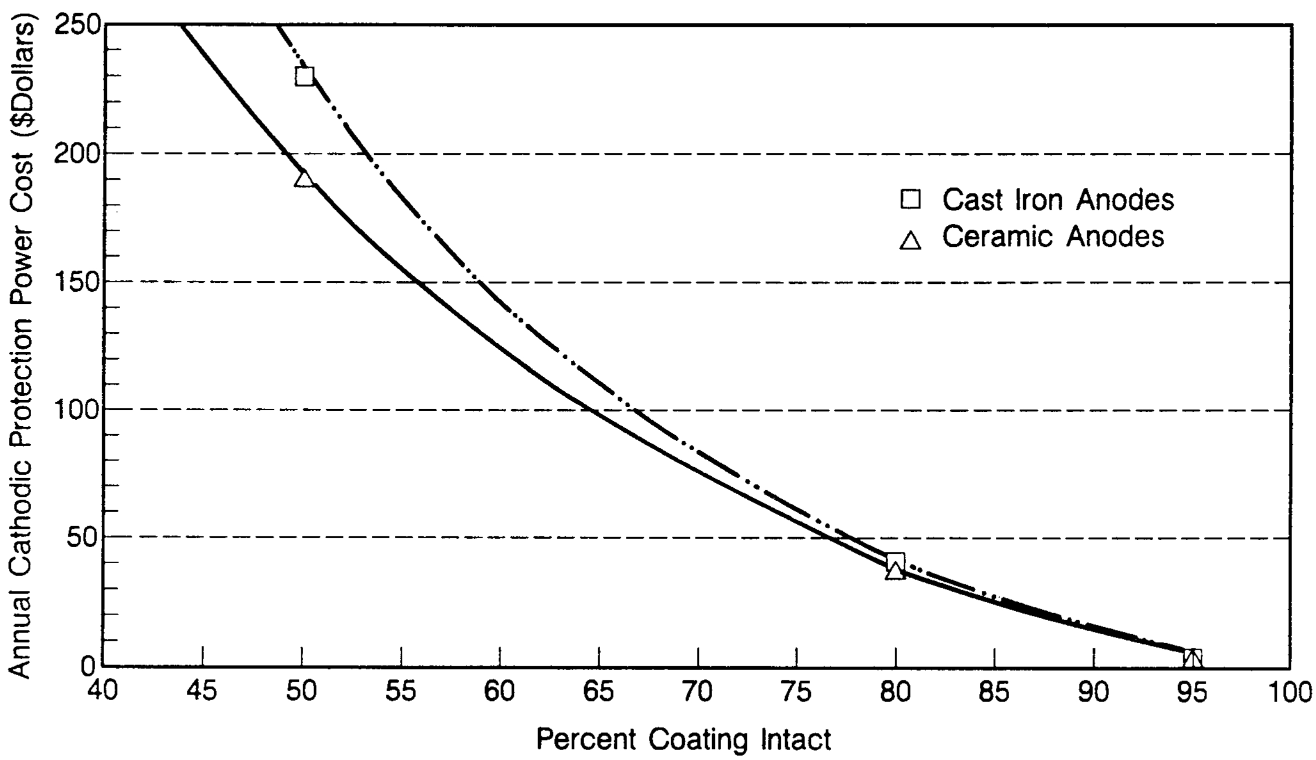

Figure 11. Cathodic Protection Power Cost Estimates for HSCBCI and Ceramic-Coated Anodes.

Table 5

Summary of Cost Estimates for HSCBCI and Ceramic-Coated Anode CP Systems

	HSCBCI (Button/String)		Ceramic (LSA Disk and Expand-A-rod)		Ceramic (LSA Disk and Continuous Rod)	
Gate Surface	**Labor**	**Materials**	**Labor**	**Materials**	**Labor**	**Materials**
USS/USG	$30,030.00	$32,435.11	$21,153.00	$40,846.94	$21,135.00	$36,368.29
DSS/USG	$26,680.50	$30,994.57	$21,095.00	$37,894.94	$21,095.00	$28,919.23
USS/DSG	$34,034.00	$38,120.57	$23,023.00	$48,124.19	$23,023.00	$42,794.08
DSS/DSG	$34,116.50	$26,917.87	$23,105.00	$41,764.18	$23,105.50	$39,490.59
Total cost	$253,329.12		$257,006.75		$235,948.69	

6 CONCLUSIONS AND RECOMMENDATIONS

This study concludes that:

1. The ceramic-coated anode systems installed on the Pike Island auxiliary miter gate, the Cordell Hull tainter gate, and the Cape Canaveral sector gate are functioning as designed. The potential surveys, after adjustment to the rectifiers, meet the National Association of Corrosion Engineers (NACE 1992) criterion of 100 mV polarization decay or at least -0.85 volts as measured between the structure and a $Cu/CuSO_4$ reference half-cell contacting the electrolyte at the Pike Island Auxiliary lock miter gate and the Cape Canaveral sector gate. The tainter gate at Cordell Hull essentially meets the 100 mV polarization decay criteria except for two locations that were slightly below the 100 mV polarization decay due to one damaged anode disk.

2. The total materials and installation costs of the ceramic-coated anode systems are estimated to be approximately equal (± 10 percent) to the equivalent HSCBCI anode system.

3. The estimated annual power cost for the ceramic-coated anode system is approximately equal to an equivalent CP system using HSCBCI anodes. At high coating efficiencies, the HSCBCI anodes are slightly more efficient (1.6 percent), but at all other coating conditions, the ceramic anode is more efficient.

4. The self-healing titanium anode-to-wire connections allow the ceramic-coated disk anodes to be installed underwater without the expense of dewatering. This was validated at Pike Island and Cape Canaveral.

It is recommended that:

1. Ceramic anode cathodic protection systems for lock and dam gates are an effective alternative to silicon iron (HSCBCI) anode systems. Based on the effectiveness and cost data, ceramic-coated anode systems should be allowed as alternatives to silicon iron systems in guide specification CW 16643, "Cathodic Protection Systems (Impressed Current) for Lock Miter Gates."

2. If the ceramic anode cathodic protection system is selected, the design steps outlined in Appendix A of this report and in ETL 1110-9-10 (Appendix B) should be used.

3. The sequence described in Chapter 3, "Criteria for Field Assessment of Cathodic Protection Systems" should be used in annual potential surveys.

4. If the structure is located in a region of extreme temperature change such as on the Ohio River, automatic potential control rectifiers should be used to adjust for the change in current requirements due to change in temperature (as much as ± 30 °F).

5. A side-by-side comparison of the durability of ceramic anode cathodic protection systems with silicon iron (HSCBCI) anode systems should be conducted.

METRIC CONVERSION TABLE

1 mil	=	0.0025 cm
1 in.	=	25.4 mm
1 in.	=	2.54 cm
1 sq in.	=	6.452 cm^2
1 ft	=	0.305 m
1 sq ft	=	0.093 m^2
1 cu ft	=	0.028 m^3
1 mi	=	1.61 km
1 lb	=	0.453 kg
1 mil	=	0.00254 cm
°F	=	(°C × 1.8) + 32

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* Anode configurations
** Materials development and testing
*** Field test and ceramic anode designs

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* Anode configurations
** Materials development and testing
*** Field test and ceramic anode designs

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ABBREVIATIONS

CP	Cathodic protection
HSCBCI	High silicon chromium bearing cast iron
MMO	Mixed metal oxide
LSA	Life-Saver Anode
CE	Coating efficiency
$Cu/CuSO_4$	Copper/copper sulfate
NACE	National Association of Corrosion Engineers
DVM	Digital voltmeter
Ag/AgCl	Silver/silver chloride
IOP	Instant off potential
ON	On potential
OFF	Off potential
DECAY	Polarization decay/buildup
NATIVE	Native potential
USG	Upstream gate
DSG	Downstream gate
USS	Upstream side
DSS	Downstream side
RW	River wall
IW	Island wall
PE	Polyethylene
PVC	Polyvinyl chloride

APPENDIX A: Detailed Cathodic Protection Design Procedures for Pike Island Auxiliary Lock Gates

1.0 DESIGNS FOR LOCK GATES

Figures 4 and 5 show a Pike Island auxiliary miter gate. This gate is approximately 62 feet long and 35 feet high. With the river at normal water level, portions of each gate will always be submerged and other portions may be submerged or exposed as lockages occur. During times of high water, more gate surfaces will be submerged, and under conditions of flood, the entire gates may be submerged. The usual water depth is 30 feet.

The gates are constructed of welded structural steel construction, horizontally framed, with a cast pintle. The downstream side of the gate consists of pattern of rectangular chambers closed on five faces and open to the water on the sixth face. The upstream face of the gate is made up of a large skin plate over the major portion of the face, and two columns of small chambers at the quoin and miter ends of the gate.

The main (large) chambers on the downstream face of the gate are set in four columns and are approximately 12 feet wide, varying in height from 3 feet 4 inches to 6 feet high, with a depth of 3 feet 6 inches. The two sets of vertically aligned chambers, at the quoin and miter ends of the gates, each are much smaller and irregularly shaped. There are six horizontally aligned rows of chambers placed one above the other in each vertical column, giving a total of 48 chambers on the downstream side.

DESIGN DATA

1) The lock is located in freshwater with a resistivity of 3000 ohm-centimeters.

2) Water velocity is less than 5 ft/s.

3) Water contains debris and icing will occur in the winter.

4) The gate surfaces have a new vinyl paint coating, minimum of 6 mils thick, with not more than 1 percent of the area bare because of holidays in the coating.

5) The coating will deteriorate significantly in 20 years of exposure. Experience shows that 30 percent of the area will become bare in 20 years.

6) Design for 7.0 mA/ft^2 (moving fresh water).

7) Electric power is available at 120/240 volts AC, single phase at the lock site.

8) Design for 20 year life.

9) Design for entire surface of the gate to be submerged.

10) Base anode requirement on the average current requirement over the anode design life.

11) Base rectifier requirement on maximum (final) current requirement at end of anode design life.

COMPUTATIONS

1) Find the surface area to be protected.

A) Upstream side.

Area of skin plate: 47.6 ft x 35.0 ft = 1666 sq ft

Chamber areas at each end (same at each end):
6 chambers @ 70 sq ft = 420 sq ft
6 chambers @ 40 sq ft = 240 sq ft
6 chambers in each vertical column

B) Downstream side

Number of of Chambers	Chamber Area (ft^2)	Total Area (ft^2)
4	63	252
4	71	284
4	76	304
4	87	348
4	92	368
4	145	580
4	158	632
4	167	668
4	179	716
2	186	372
4	195	780
2	206	412
2	228	456
2	239	478

Total Number of Chambers = 48
Total Chamber Area = 2092 ft^2
Total Area = 6650 ft^2

2) Calculate the current requirements (I) from Equation 1.

$$I = A * I' (1.0 - C_E) \qquad \text{(Eq 1)}$$

where:

A - Surface area to be protected (varies depending on portion of structure).
I'- Required current density to adequately protect gate (7.0 mA/ft^2).
C_E = Coating efficiency (0.99 initial, and 0.70 final).

A) Upstream side

Skin plate current requirement

Calculate I

where: A = 1666 ft^2 (From computation step 1A).

Initial current requirement (C_E = 99%):

I = 1666 ft^2 x 7.0 mA/ft^2 x (1 - 0.99) = 116 mA (use 120 mA)

Final current requirement (C_E = 70%):

I = 1666 ft^2 x 7.0 mA/ft^2 x (1 - 0.70) = 3498 mA (use 3500)

Average current requirement:

I = (120 + 3500)/2 mA = 1810 mA (use 2 A for skin plate)

End chamber current requirement

To be able to use the same anode assembly in each set of chambers, base the design on the larger of the two chambers at each end.

Calculate I

where: A = 420 ft^2 (From computation step 1A).

Initial current requirement (C_E = 99%):

I = 420 ft^2 x 7.0 mA/ft^2 x (1 - 0.99) = 29.4 mA (use 30 mA per 6 chambers).

Final current requirement (C_E = 70%):

I = 420 ft^2 x 7.0 mA/ft^2 x (1 - 0.70) = 882 mA (use 900 mA per 6 chambers).

Average current requirement:

$I = (30 + 900)/2 = 465$ mA per 6 chambers (use 0.5 A per 6 chambers in a vertical column).

This is current requirement for one vertical column of 6 chambers. Total average current requirement is four times this amount:

$I = 0.5 \times 4 = 2.0$ A for chamber

Total current requirement for upstream side:

$I_T = 120$ mA + (4 x 30 mA) = 240 mA = 0.24 amps (initial)
$I_T = 2.0$ A + 2.0 A = 4.0 amperes (average)
$I_T = 3500$ mA + (4 x 900 mA) = 7100 mA = 7.10 amps (final)

B) Downstream side

Base design on largest chamber to allow the use of the same anode in all chambers.

Calculate I

where: $A = 239\ ft^2$ (From computational step 1B).

Initial current requirement ($C_E = 99\%$):

$I = 239\ ft^2 \times 7.0\ mA/ft^2 \times (1 - 0.99) = 16.8$ mA per chamber

Final current requirement ($C_E = 70\%$):

$I = 239\ ft^2 \times 7.0\ mA/ft^2 \times (1 - 0.70) = 502$ mA per chamber

Average current requirement:

$I = (16.8 + 502)/2 = 260$ mA per chamber

Total current requirement for downstream side (42 chambers):

$I_T = 16.8$ mA/chamber x 48 chamber = 806 mA = 0.8 A (initial)
$I_T = 260$ mA/chamber x 48 chamber = 12480 mA = 12.4 A (ave)
$I_T = 502$ mA/chamber x 48 chamber = 24096 mA = 24.2 A (final)

C) Total current requirement

Initial		
Upstream side	=	0.24 amps
Downstream side	=	0.80 amps
		1.04 amps
Average		
Upstream side	=	4.0 amps
Downstream side	=	12.4 amps
		16.4 amps
Final		
Upstream side	=	7.1 amps
Downstream side	=	24.2 amps
		31.3 amps

Note: Average current requirements determine anode selection. Final current requirements determine rectifier selection.

3) Select the anode and calculate the number of anodes required (N) to meet the design life requirements.

Disc anodes such as those shown in Figure 2 are considered best for the skin plate on the upstream side. Either 1/8 inch diameter segmented rod anodes consisting of 4 foot segments, as shown in Figure 3, or continuous 1/8 inch diameter prefabricated rod anodes are considered best for the chambers.

For this example, we will design based on the 4 foot segments. The design for the continuous rod material would be identical since they have the same amperage capacity per lineal foot of anode material. Number of anodes is calculated from Equation 2.

$$N = \frac{I}{I_A} \qquad \text{(Eq 2)}$$

where:

I = Total current requirement.
I_A = Average current per anode for the anode's desired life.

A) Upstream side

Skin plate - Number of disc anodes

Calculate N

where: $I = 2$ A (from step 2A)
$I_A = 0.84$ A/disc anode

$$N = \frac{1}{0.84} = 2.4 \text{ anodes; use 3 disc anodes}$$

Chambers - Number of segmented rod anodes

For each set of 6 chambers in a vertical column

Calculate N

where: $I = 0.5$ A (from step 2A)
$I_A = 1.0$ A/4 ft long segmented rod (from Table A-1)

$$N = \frac{0.5}{1} = 0.5 \text{ anodes; use 1 segmented rod anode per 6 vertical chambers}$$

B) Downstream side

$I = 260$ mA per chamber

For each set of 6 chambers in a vertical column:

$I = 6 \times 260$ mA $= 1560$ mA $= 1.56$ A
$A = 1.0$ A/anode (from Table A-1)

$$N = \frac{1.56}{1} = 1.56 \text{ anodes; use 2 segmented rod anode per 6 vertical chambers}$$

4) Select number of anodes to provide adequate current distribution.

A) Upstream side

Skin plate

Experience shows that an anode grid spacing of 10 to 12 feet provides adequate coverage of protective current. Additional anodes are also needed along the bottom of the gate, as this is an area where coating damage occurs readily, thus exposing an appreciable amount of bare metal. Figure 4 shows a suitable configuration using a combination of 19 disc anodes.

Table A-1
Dimensions and Ratings of Ceramic Anodes
Underground Usage

Wire and Rod Anodes (Packaged)

Anode Element Dimension	Package Size (in.)	Weight (lb)	Current Rating (amperes) 10-Year Design Life	15-Year Design Life		20-Year Design Life	
			HDC	HDC*	SC**	HDC*	SC**
1/8" x 2'	2 x 30	6	1.3	1.10	0.6	0.9	0.5
1/16" x 5'	2 x 72	14	1.5	1.25	0.7	1.0	0.6
1/16" x 5'	3 x 72	26	1.5	1.25	0.7	1.0	0.6
1/8" x 4'	2 x 60	12	2.7	2.2	1.2	1.8	1.0
1/8" x 4'	3 x 60	22	2.7	2.2	1.2	1.8	1.0
1/4" x 4'	3 x 60	22	5.5	4.4	2.4	3.5	2.0
1/8" x 6'	3 x 96	35	4.0	3.3	1.8	2.7	1.5
3/8" x 4'	3 x 60	22	7.5	6.0	3.6	5.1	3.0
1/2" x 4'	3 x 60	23	10.0	8.0	4.8	6.8	4.0
3/4" x 4'	3 x 60	24	15.0	12.0	7.2	10.0	6.0
1/8" x 6'	3 x 96	35	4.0	3.3	1.8	2.7	1.5
1/4" x 6'	3 x 96	35	8.2	6.6	3.6	5.3	3.0
1/8" x 8'	3 x 120	44	5.4	4.4	2.4	3.6	2.0
1/4" x 8'	3 x 120	44	11.0	8.8	4.8	7.0	4.0

*Heavy duty coating tubular anodes (in coke breeze)
**Standard coating tubular anodes (in coke breeze)

Anode Element Dimension	Current Rating - Amp 20-Year Design Life
1" x 9.8"	2.00 amp
1" x 19.7"	4.00 amp
1" x 39.4"	8.00 amp
0.63" x 9.8"	1.25 amp
0.63" x 19.7"	2.50 amp
0.63" x 39.4"	5.00 amp

Table A-1 (Cont'd)
Fresh and Seawater Usage

Wire and Rod Anodes (Bare)

Life (years)	Fresh Water	Brackish Water	Seawater
Maximum Current/1-ft Length for 20-Year Design Life of .0625 in. Dia. Wire			
10	0.39	0.51	0.85
15	0.31	0.44	0.74
20	0.26	0.39	0.67
Maximum Current/1-ft Length for 20-Year Design Life of .125 in. Dia. Rod or Wire			
10	0.79	1.02	1.70
15	0.62	0.88	1.47
20	0.52	0.79	1.33
Maximum Current/1-ft Length for 20-Year Design Life of .25 in. Dia. Rod			
10	1.58	2.04	3.41
15	1.24	1.76	2.95
20	1.04	1.58	2.66
Maximum Current/1-ft Length for 20-Year Design Life of .325 in. Dia. Rod			
10	2.37	3.06	5.11
15	1.85	2.63	4.42
20	1.56	2.37	3.99
Maximum Current/1-ft Length for 20-Year Design Life of .5 in. Dia. Rod			
10	3.16	4.08	6.81
15	2.47	3.51	5.90
20	2.08	3.16	5.33
Maximum Current/1-ft Length for 20-Year Design Life of .625 in. Dia. Rod			
10	3.95	5.10	8.52
15	3.09	4.39	7.37
20	2.60	3.95	6.66
Maximum Current Per 1-ft Length for 20-Year Design Life of .75 in. Dia. Rod			
10	4.74	6.12	10.22
15	3.71	5.27	8.85
20	3.12	4.74	7.99

Table A-1 (Cont'd)
Fresh and Seawater Usage

Tubular Anodes (Bare)

Seawater - Current in amp per anode (15-Year Design Life)	
1 in. x 19.7 in.	25 amp
1 in. x 39.4 in.	50 amp
0.63 in. x 19.7 in.	15 amp
0.63 in. x 39.4 in.	30 amp
Sea Mud - Current in amp per anode (20-Year Design Life)	
1 in. x 19.7 in.	6 amp
1 in. x 39.4 in.	12 amp
Fresh Water - Current in amp per anode (20-Year Design Life)	
1 in. x 19.7 in.	4.00 amp
1 in. x 39.4 in.	8.00 amp
0.63 in. x 19.7 in.	2.50 amp
0.63 in. x 39.4 in.	5.00 amp

Current Density Limitations

Wire and Rod Anode
Anode Life Versus Maximum Current Density (ampere/sq ft)

Life (years)	Coke*	Fresh Water	Brackish Water	Seawater
10	19	24	31	52
15	15	19	27	45
20	13	16	24	41

Table A-1 (Cont'd)

Tubular Anodes
Anode Life Versus Maximum Current Density (ampere/sq ft)

Life (years)	Fresh Water	Brackish Water	Seawater
20	9.3	9.3	56

Disc Anodes (see figure 2)

Size:	5-in. diameter (Typical - Other sizes available)		
Active Area:	19 sq in.		
Weight:	2.0 lb		
		Fresh Water	Salt Water
Current Capacity - 20-year life (amp/anode)		0.84	5.00
Operating voltage - 20-year life (V)		20.0	10.0

Segmented Rod Anodes (see figure 3)

Size:	4-ft length; 0.138 in. diameter		
Active Area:	22 sq in.		
Weight:	2.3 oz		
		Fresh Water	Salt Water
Current Capacity - 20-year life (amp/anode)*		1.00	2.50
Operating voltage - 20-year life (V)		50.0	10.0

*Standard Coating

Chambers

A continuous length of screw coupled segmented rod anodes is needed for each chamber column at the miter and quoin ends extending from the high water line down to within 2 feet of the bottom girder. Each anode consists of 7 segments, each 4 feet in length. Four segmented rod anode assemblies are thus required, comprising a total of 28 segments, each 4 feet in length. See Figure 5.

Total anodes required for the upstream side:

19 disc anode
4 segmented rod anode (28 individual rod segments)

B) Downstream side

One continuous length of screw coupled segmented rod anodes is needed for each chamber column extending from the high water line down to within 2 feet of the bottom girder. (NOTE: For the downstream side of the downstream gates, a much shorter anode length will be required since only the lower portions of this gate surface are ever submerged.) Each anode rod consists of 7 segments each 4 feet in length. Eight segmented rod anodes are thus required, comprising a total of 56 segments, each 4 feet in length. See Figure 5.

5) Determine the anode-to-water resistance (R_A) of the individual anodes.

Disc anodes

Empirical information indicates anode-to-water resistance (R_A) of a single 5 inch disc anode on a coated structured may be expressed by the Equation 3.

$$R_A = \frac{p}{21.5} \qquad \text{(Eq 3)}$$

where: p = 3000 ohm-cm (Water resistivity from design item 1).

$$R_A = \frac{3000}{21.5} = 139.5 \text{ ohms}$$

The disc anodes-to-water resistance (R_N) of the 19 disc anodes can be approximated from Equation 4.

$$R_N = R_A/N + (p * P_F)/C_C \qquad \text{(Eq 4)}$$

where: R_A = 139.5 ohms (The disc anode-to-water resistance of individual disc anodes from previous calculation)
N = 19 (Number of anodes, design step 4)
p = 3000 ohm-cm
P_F = 0.00140 (Paralleling factor from Table A-2)
C_C = 10 ft (Center-to-center spacing of disc anodes).

$$R_N = 139.5/19 + (3000 \times 0.00140)/10 = 7.7 \text{ ohms}$$

At the maximum expected current of 3500 mA (3.5 amps), the voltage required for the disc anodes can be determined using Ohm's Law, Equation 5.

$$E = I \times R \qquad \text{(Eq 5)}$$

$$E = 3.5 \times 7.7 = 27 \text{ volts}$$

This is a reasonable voltage, so the 19 disc anodes are sufficient.

<u>Segmented rod anodes</u>

The segmented rod anode-to-water resistance (R_A) is calculated from Equation 6. The total length of anode is used, although a shorter length could be used if low water conditions were expected most of the time.

$$R_A = \frac{0.0052 \times p}{L} \times [\ln (8L/d) - 1] \qquad \text{(Eq 6)}$$

where: p = 3000 ohm-cm (Water resistivity from design item 1)
L = 28 ft (Length of anode rod from design step 4)
d = 0.0115 ft (Anode rod diameter)

$$R_A = \frac{0.0052 \times 3000}{28} \times [\ln \frac{8 \times 28}{0.0115} -1]$$

$$R_A = 0.557 [9.88 - 1] = 4.95 \text{ ohms}$$

Table A-2
Anode Paralleling Factors (P) for Various Number of Anodes (N) Installed in Parallel

N	P	N	P
2	0.00261	14	0.00168
3	0.00289	16	0.00155
4	0.00283	18	0.00145
5	0.00268	20	0.00135
6	0.00252	22	0.00128
7	0.00237	24	0.00121
8	0.00224	26	0.00114
9	0.00212	28	0.00109
10	0.00201	30	0.00104
12	0.00182		

Voltage for upstream side rod anodes

At the maximum expected current requirement for the upstream chambers of 900 mA per vertical column of 6 chambers, the voltage required for each rod anode can be determined using Ohm's Law, Equation 5.

$$E = I \times R = 0.90 \text{ amps} \times 4.95 \text{ ohms} = 4.46 \text{ volts}$$

This is a reasonable voltage, so the single anode per column of chambers is sufficient.

Voltage for downstream side rod anodes

At the maximum expected current of 251 mA per chamber, the current required for one vertical column of 6 chambers is:

$$I = 6 \times 502 \text{ mA} = 3012 \text{ mA or } 3.0 \text{ amperes}$$

The voltage required for each anode is, Equation 5:

$$E = I \times R = 3.0 \text{ amps} \times 4.95 \text{ ohms} = 14.9 \text{ volts}$$

This is a reasonable voltage, so the single anode per vertical column of chamber is sufficient.

6) Determine total circuit resistance (R_T) using Equation 7.

$$R_T = R_N + R_W + R_C \qquad \text{(Eq 7)}$$

where: R_N = Anode-to-water resistance.
R_W = Header cable/wire resistance.
R_C = Tank-to-water resistance.

A) Upstream side

Skin plate

R_N = 7.7 ohms (Anode-to-water resistance).
R_W = 0.02 ohms (Wire resistance)

R_W depends on the actual wiring of the anodes, but the general arrangement would be to use a header cable from the rectifier to the center of the disc anode array and then distribute the current through a junction box to each anode. Wiring would be in conduit on the inside of the gate. Assuming the rectifier is 28 feet from the gate, there will be about 100 feet of positive and negative header cable. No. 2 AWG, HMWPE insulated cable is selected. The resistance of the anode

distribution wiring is considered negligible. The header cable resistance is calculated from Equation 8.

$$R_W = \frac{L_W R_{MFT}}{1000} \qquad \text{(Eq 8)}$$

where: L_W = 100 ft (Header cable length [As noted above])
R_{MFT} = 0.159 ohms (Resistance per 1000 linear feet of No. 2 AWG HMWPE).

$$R_W = \frac{100 \times 0.159}{1000} = 0.016 \text{ ohms; use } 0.02 \text{ ohms}$$

R_C = 0.00 ohms (The structure-to-water resistance)

R_C is considered negligible since the design maximum capacity is based on a 30 percent bare structure which would have negligible resistance.

The total resistance R_T of the skin plate disc anode system using Equation 7 is:

$$R_T = R_N + R_W + R_C = 7.7 + 0.02 + 0.0 = 7.72 \text{ ohms}$$

<u>Chambers</u>

Total resistance of the 4 upstream chamber anodes (R_N) is calculated as follows. The 4 anode rods are in parallel. Total resistance can be determined from the law of parallel circuits. Since all 4 anodes have the same anode-to-water resistance, the calculation becomes Equation 9.

$$R_N = R_A/N = 4.95/4 = 1.24 \text{ ohms} \qquad \text{(Eq 9)}$$

where: R_N = Total resistance of all 4 anodes.
R_A = 4.95 (Anode-to-water resistance).
N = 4 (Number of anodes)

R_W = 0.01 ohms (Wire resistance)

R_W consists of a No. 2 AWG, HMWPE insulated cable. The rectifier will be located about 25 feet from the gate, requiring 50 feet of positive and negative header cable to the gate.

There will be about 60 feet of cable on the gate. One half of the cable resistance is used in the calculation to allow for distribution of current.

Total wire length then is: 50 ft + 30 ft = 80 ft

Resistance, R_W, is calculated from Equation 8:

$$R_W = \frac{L_W R_{MFT}}{1000} \qquad \text{(Eq 8)}$$

where: L_W = 80 ft (Header cable length[As noted above])
R_{MFT} = 0.159 ohms (Resistance per 1000 linear feet of No. 2 AWG HMWPE).

$$R_W = \frac{80 \times 0.159}{1000} = 0.01 \text{ ohms}$$

R_C = 0.00 (Structure-to-water resistance is negligible.

Total resistance (R_T) of the upstream chamber system then from Equation 7:

$$R_T = R_N + R_W + R_C \qquad \text{(Eq 7)}$$

$$R_T = 1.24 + 0.01 + 0.0 = 1.25 \text{ ohms}$$

B) Downstream side

Calculations are similar to those for the upstream chambers. Anode-to-water resistance, R_N, from Equation 9 is:

$$R_N = R_A/N$$

where: R_A = 4.95 ohms (From design step 5).
N = 8 anode rods (From design step 3).

R_N = 4.95/8 = 0.62 ohms
R_W = 0.01 ohms wire resistance: (Wire length and resistance is the same as the upstream side).

Total resistance (R_T) from Equation 7:

$$R_T = R_N + R_W + R_C = 0.62 + 0.01 + 0.0 = 0.63 \text{ ohms}$$

7) Determine required rectifier voltage (V_{REC}) and current.

A) Upstream side

Skin plate

Maximum current required: 3.50 A (step 2a)

Resistance: 7.72 ohms (from step 6a)

Voltage required, Equation 5: E = I x R = 3.5 x 7.72 = 27 volts

Chambers

Maximum current required: 3.6 amperes (from step 2a)

Resistance: 1.25 ohms (from step 6a)

Voltage required, Equation 5: E = I x R = 3.6 x 1.25 = 4.5 volts

B) Downstream side

Maximum current required: 24.2 amperes (from step 2b)

Resistance: 0.63 ohms (from step 6b)

Voltage required, Equation 5: E = I x R = 24.2 x 0.63 = 15.3 volt

SELECTION OF RECTIFIER

The largest design voltage requirement is 27 volts. Using a factor of safety of 120%, rectifier voltage is calculated:

27 volts x (120%) = 33 volts

Total current required:

Upstream skin plate	=	3.50 amperes
Upstream chambers	=	7.1 amperes
Downstream chambers	=	24.2 amperes
		34.8 amperes

A commercially available rectifier having an output of 40 volts, 40 amperes is chosen. Because of the different circuit resistances, separate control over each circuit is required. This is best handled by a rectifier having 3 separate automatic constant current output circuits. Figure A-1 shows the circuitry.

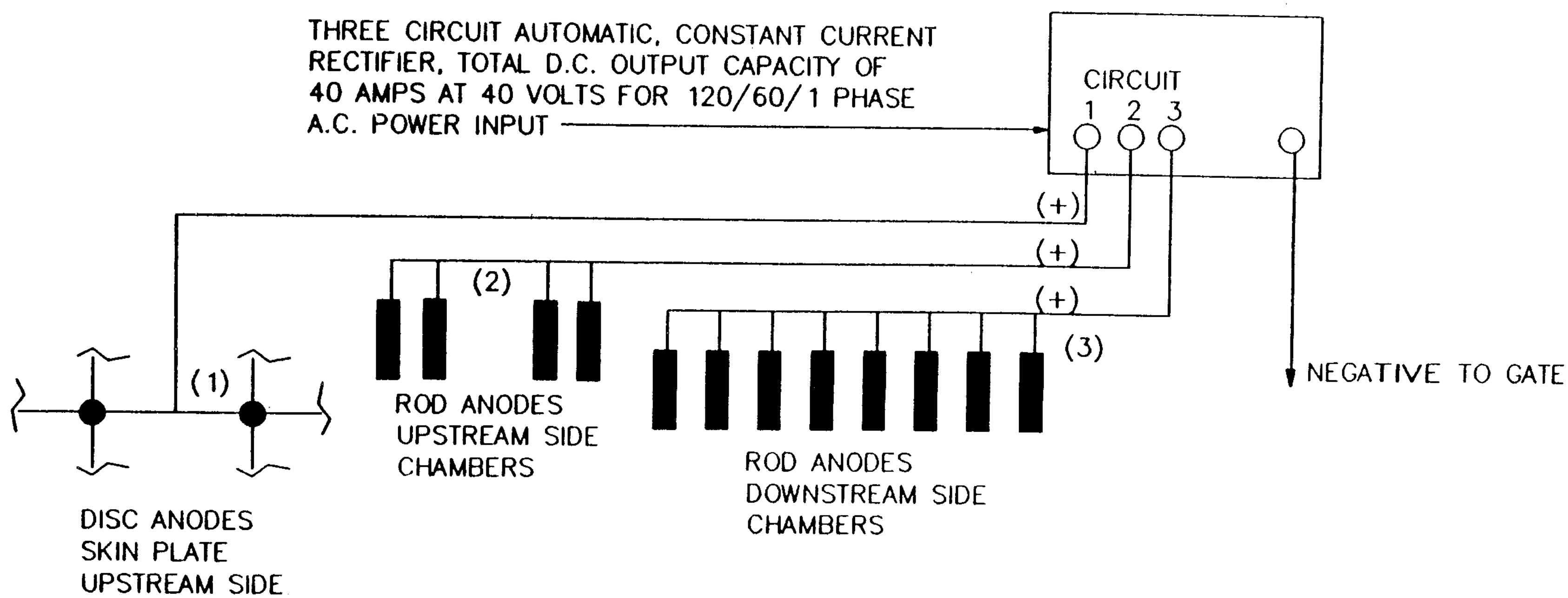


Figure A-1. Circuit Diagram Lock Miter Gate.

ROD ANODE INSTALLATION

Rod anodes can be supported by the cable from a clevis at the top of the gate. Since ice and debris are expected, the anodes need to be protected. This is best done by installing them within perforated polyethylene or fiberglass pipes. A steel half pipe bumper is used outside the plastic pipe. The anodes may be secured at the bottom using a stabilizing weight or stand off device.

OTHER GATE APPLICATIONS

Anode configurations for a Cordell Hull tainter gate and a Cape Canaveral sector gate are shown in Figures 6 and 7.

APPENDIX B: Specification for Ceramic Coated Anode Material

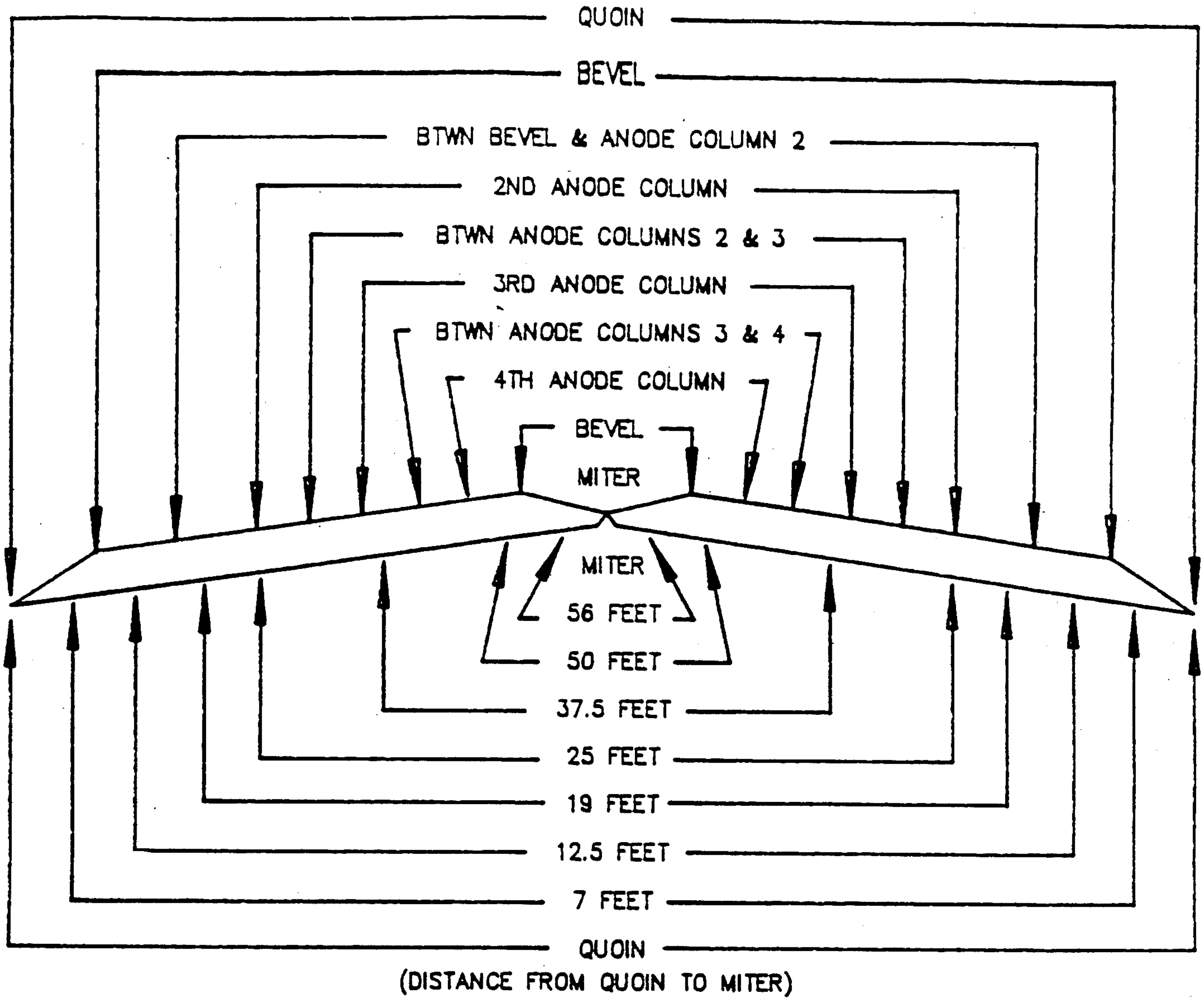
1.0 CONDUCTIVE CERAMIC ANODE MATERIAL

The electrically conductive ceramic coating shall contain a mixture consisting primarily of iridium, tantalum and titanium oxides. Although the exact composition of the conducting oxide layer can vary, the average composition is generally a 50/50 atomic percent mixture of iridium and titanium oxides, with a small amount of tantalum. In addition, it is the manufacturer's responsibility to test the resistivity (no less than 0.002 ohm-centimeter), bond strength (greater than 50 MPa), and current capacity life, in order to guarantee the quality of the conductive ceramic coating. The adhesion or bond strength shall be determined by epoxy bonding a 2.54 mm diameter stud to the ceramic coating and measuring the load to failure of either the epoxy (about 70 MPa) or the interface between the coating and the substrate. The anode must be inert and the electrically conductive ceramic coating dimensionally stable. The ceramic coated anode shall be capable of sustaining a current density of 100 ampere/meter^2 in an oxygen generating electrolyte at 150°F for 20 years, to insure the current capacity life. An accelerated current capacity life test must be performed by the manufacturer on every lot of anode wire used to construct the anode as described in section 2.0.1.1. The mixed metal oxide coating shall be applied to the wire anode by a firm which is regularly engaged in and has a minimum 5 years experience in manufacturing and applying mixed metal oxide coatings to titanium anode substrates. The mixed metal oxide must be sintered to the titanium surface in such a way that it remains tightly bound to the surface when bent 180° onto itself.

1.01 Accelerated Anode Life Test (To be Conducted by the Manufacturer)

The anode wire material is to be suitable for sustaining current densities of 100 ampere/meter^2 in an oxygen generating electrolyte for 20 years. The manufacturer shall certify that a representative sample taken from the same lot used to construct the anode, has been tested and meets the following criteria. The test cell is able to sustain a current density of 10,000 ampere/meter^2 in a 15 weight percent sulfuric acid electrolyte at 150°F without an increase in anode to cathode potential of more than 1 volt. The cell containing the anode shall be powered with a constant current power supply for the 30 day test period. The representative sample shall be 5" in length and be taken from the lot of wire which is to be used for the anode.

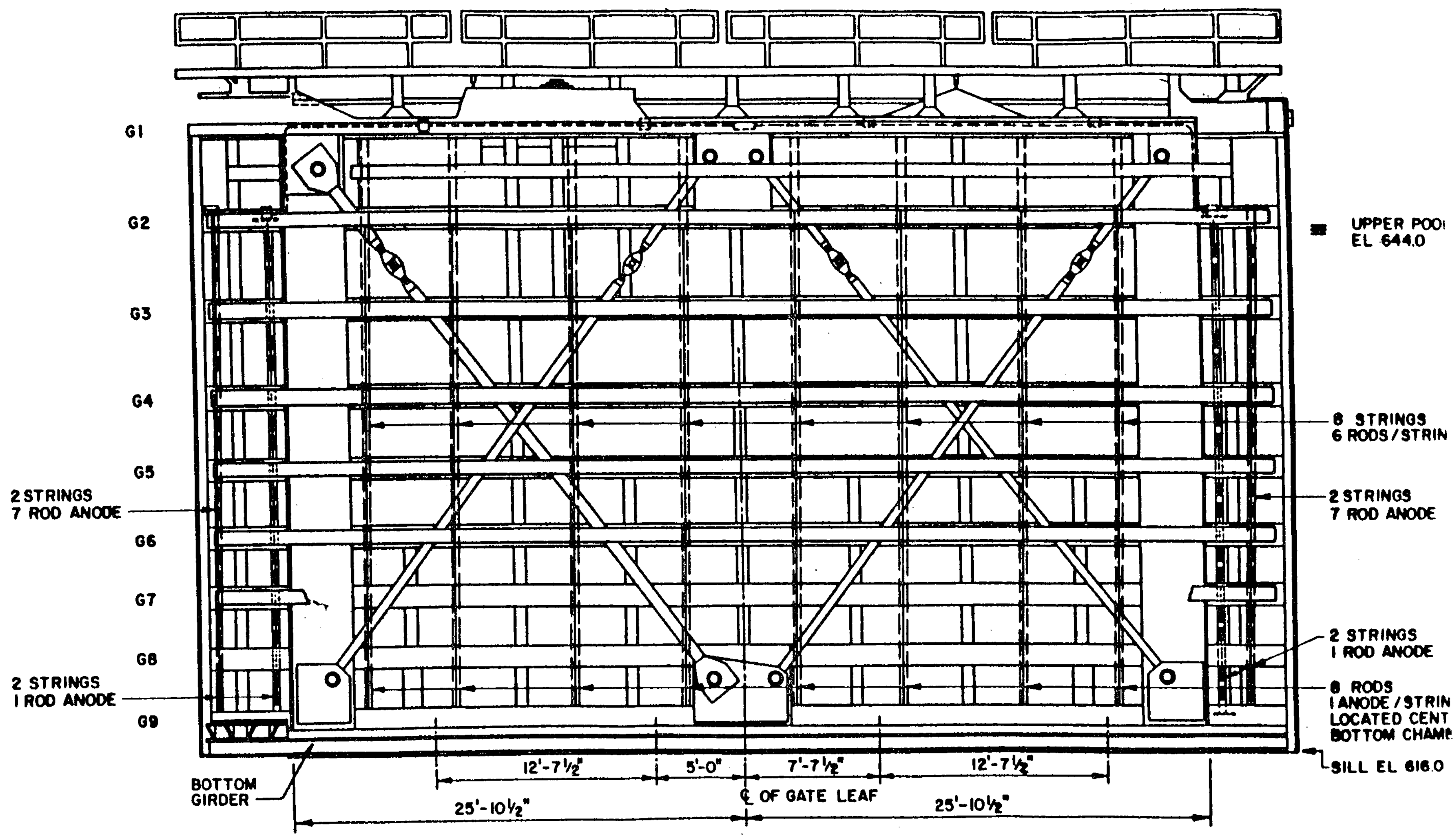
APPENDIX C: Potential Survey Data of Pike Island Auxiliary Lock (Upstream Gate/Upstream Side)



PIKE ISLAND AUXILIARY LOCK

TOP VIEW OF MITER GATE
(DRAWING APPLIES TO UPPER & LOWER GATES)

REFERENCE CELL LOCATIONS
FOR POTENTIAL MEASUREMENTS



UPPER GATE
COMPARTMENT (DOWNSTREAM) SIDE

PIKE ISLAND AUXILIARY LOCK
Up Stream Gate/Up Stream Side

ISLAND WALL LEAF

DEPTH	Quoin (Island Wall) ON	OFF	DECAY	DELTA	Bevel ON	OFF	DECAY	DELTA	Between Bevel & Anode ON	OFF	DECAY	DELTA
Bottom	0.818	0.796	0.697	0.099	0.873	0.808	0.702	0.106	0.854	0.793	0.702	0.091
3	0.830	0.766	0.678	0.088	0.891	0.808	0.703	0.105	0.896	0.797	0.632	0.165
6	1.066	0.911	0.781	0.130	1.054	0.927	0.756	0.171	1.053	0.879	0.642	0.237
9	1.206	0.996	0.848	0.148	1.147	0.994	0.815	0.179	1.137	0.928	0.630	0.298
12	1.293	1.026	0.686	0.340	1.149	1.019	0.850	0.169	1.157	0.945	0.609	0.336
15	1.356	1.049	0.883	0.166	1.249	1.023	0.845	0.178	1.209	0.963	0.614	0.349
18	1.396	1.050	0.884	0.166	1.299	1.030	0.850	0.180	1.261	0.976	0.594	0.382
21	1.427	1.060	0.882	0.178	1.307	1.046	0.853	0.193	1.244	0.979	0.636	0.343
24	1.450	1.053	0.878	0.175	1.350	1.047	0.848	0.199	1.235	0.965	0.602	0.363
27	1.413	1.041	0.860	0.181	1.293	1.048	0.818	0.230	1.213	0.951	0.573	0.378
30	1.324	1.012	0.182	0.182	1.099	1.009	0.800	0.209	0.933	0.896	0.618	0.278

DEPTH	2nd Anode Column ON	OFF	DECAY	DELTA	Between Anode Columns ON	OFF	DECAY	DELTA	3rd Anode Column ON	OFF	DECAY	DELTA
Bottom	0.912	0.815	0.673	0.142	0.858	0.778	0.657	0.121	0.836	0.753	0.638	0.115
3	0.931	0.812	0.677	0.135	0.900	0.760	0.655	0.105	0.789	0.733	0.644	0.089
6	1.209	0.888	0.704	0.184	1.300	0.859	0.681	0.178	1.162	0.847	0.680	0.167
9	1.184	0.894	0.708	0.186	1.147	0.901	0.679	0.222	1.149	0.885	0.688	0.197
12	1.129	0.892	0.706	0.186	1.078	0.904	0.668	0.236	1.098	0.887	0.689	0.198
15	1.183	0.905	0.710	0.195	1.122	0.881	0.696	0.185	1.176	0.886	0.694	0.192
18	1.583	0.966	0.721	0.245	1.147	0.893	0.704	0.189	1.600	0.921	0.706	0.215
21	1.176	0.910	0.712	0.198	1.140	0.905	0.703	0.202	1.178	0.897	0.698	0.199
24	1.175	0.918	0.714	0.204	1.094	0.933	0.697	0.236	1.185	0.905	0.700	0.205
27	1.321	0.981	0.749	0.232	1.147	0.924	0.704	0.220	1.900	0.970	0.711	0.259
30	1.189	0.929	0.722	0.207	1.156	0.924	0.715	0.209	1.214	0.920	0.710	0.210

DEPTH	Between Anode Columns ON	OFF	DECAY	DELTA	4th Anode Column ON	OFF	DECAY	DELTA	Bevel ON	OFF	DECAY	DELTA
Bottom	0.812	0.736	0.631	0.105	0.795	0.726	0.635	0.091	0.798	0.736	0.659	0.077
3	0.805	0.733	0.628	0.105	0.771	0.718	0.642	0.076	0.780	0.722	0.670	0.052
6	1.057	0.822	0.660	0.162	1.125	0.844	0.675	0.169	0.993	0.865	0.711	0.154
9	1.084	0.857	0.670	0.187	1.059	0.880	0.688	0.192	1.057	0.901	0.723	0.178
12	1.037	0.869	0.671	0.198	1.002	0.883	0.671	0.212	1.032	0.914	0.743	0.171
15	1.052	0.874	0.676	0.198	1.031	0.906	0.672	0.234	1.059	0.955	0.750	0.205
18	1.065	0.888	0.680	0.208	1.486	0.960	0.689	0.271	1.205	0.992	0.788	0.204
21	1.086	0.902	0.635	0.267	1.099	0.923	0.695	0.228	1.204	0.999	0.808	0.191
24	1.096	0.895	0.688	0.207	1.087	0.931	0.700	0.231	1.237	0.995	0.813	0.182
27	1.102	0.908	0.696	0.212	1.413	0.977	0.739	0.238	1.261	1.004	0.820	0.184
30	1.112	0.914	0.702	0.212	1.165	0.956	0.734	0.222	1.199	1.017	0.820	0.197

PIKE ISLAND AUXILIARY LOCK
Up Stream Gate/Up Stream Side

Miter

DEPTH	ON	OFF	DECAY	DELTA
Bottom	0.828	0.756	0.674	0.082
3	0.887	0.795	0.676	0.119
6	1.043	0.879	0.718	0.161
9	1.139	0.942	0.756	0.186
12	1.148	0.954	0.772	0.182
15	1.203	0.979	0.787	0.192
18	1.265	1.006	0.794	0.212
21	1.303	1.011	0.809	0.202
24	1.318	1.014	0.806	0.208
27	1.302	1.008	0.798	0.210
30	1.243	0.984	0.784	0.200

PIKE ISLAND AUXILIARY LOCK
Up Stream Gate/Up Stream Side

LAND WALL LEAF

	Bevel				4th Anode Column				Between Anode Columns			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.822	0.758	0.660	0.098	0.794	0.742	0.639	0.103	0.882	0.802	0.661	0.141
3	0.835	0.797	0.673	0.124	0.797	0.743	0.641	0.102	0.873	0.781	0.663	0.118
6	1.108	0.923	0.719	0.204	0.973	0.860	0.678	0.182	0.952	0.819	0.682	0.137
9	1.273	0.968	0.739	0.229	0.950	0.873	0.692	0.181	0.986	0.855	0.696	0.159
12	1.200	0.983	0.731	0.252	0.971	0.889	0.697	0.192	0.977	0.872	0.701	0.171
15	1.170	0.980	0.746	0.234	1.062	0.916	0.713	0.203	0.990	0.884	0.709	0.175
18	1.399	1.018	0.766	0.252	1.046	0.918	0.736	0.182	1.015	0.892	0.716	0.176
21	1.502	1.042	0.787	0.255	1.068	0.915	0.730	0.185	1.022	0.900	0.718	0.182
24	1.328	1.017	0.809	0.208	1.156	0.921	0.726	0.195	1.022	0.899	0.719	0.180
27	1.399	1.027	0.804	0.223	1.056	0.935	0.741	0.194	1.036	0.903	0.724	0.179
30	1.093	0.959	0.742	0.217	1.048	0.940	0.759	0.181	1.034	0.914	0.732	0.182

	3rd Anode Columns				Between Anode Columns				2nd Anode Column			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.874	0.790	0.664	0.126	0.884	0.798	0.669	0.129	0.872	0.807	0.684	0.123
3	0.838	0.788	0.668	0.120	0.851	0.780	0.668	0.112	0.908	0.812	0.692	0.120
6	1.054	0.839	0.690	0.149	1.080	0.840	0.695	0.145	1.134	0.858	0.707	0.151
9	1.073	0.873	0.705	0.168	1.082	0.889	0.705	0.184	1.164	0.885	0.713	0.172
12	1.042	0.891	0.708	0.183	1.039	0.918	0.694	0.224	1.127	0.899	0.719	0.180
15	1.074	0.893	0.711	0.182	1.109	0.901	0.714	0.187	1.159	0.908	0.723	0.185
18	1.350	0.913	0.714	0.199	1.121	0.909	0.720	0.189	1.366	0.915	0.727	0.188
21	1.087	0.901	0.719	0.182	1.139	0.912	0.723	0.189	1.190	0.916	0.728	0.188
24	1.088	0.904	0.721	0.183	1.106	0.929	0.724	0.204	1.185	0.925	0.728	0.197
27	1.219	0.914	0.727	0.187	1.102	0.929	0.729	0.200	1.269	0.926	0.730	0.196
30	1.098	0.917	0.751	0.166	1.127	0.923	0.735	0.188	1.182	0.929	0.734	0.195

	Between Anode & Bevel				Bevel				Quoin (Land Wall)			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.930	0.846	0.712	0.134	0.944	0.849	0.692	0.157	0.874	0.809	0.617	0.192
3	0.962	0.860	0.719	0.141	0.970	0.865	0.699	0.166	0.844	0.777	0.591	0.186
6	1.121	0.912	0.739	0.173	1.252	0.990	0.745	0.245	1.108	0.924	0.728	0.196
9	1.233	0.961	0.760	0.201	1.370	1.030	0.784	0.246	1.261	1.003	0.790	0.213
12	1.292	0.973	0.776	0.197	1.440	1.042	0.811	0.231	1.342	1.025	0.809	0.216
15	1.380	0.997	0.784	0.213	1.612	1.050	0.809	0.241	1.483	1.052	0.821	0.231
18	1.430	1.005	0.783	0.222	1.800	1.083	0.817	0.266	1.616	1.078	0.838	0.240
21	1.474	1.014	0.778	0.236	1.780	1.090	0.835	0.255	1.730	1.090	0.841	0.249
24	1.500	1.002	0.765	0.237	1.800	1.083	0.815	0.268	1.797	1.094	0.828	0.266
27	1.460	0.996	0.747	0.249	1.903	1.099	0.803	0.296	1.746	1.063	0.806	0.257
30	1.171	0.963	0.665	0.298	1.399	1.066	0.780	0.286	1.554	1.026	0.779	0.247

PIKE ISLAND AUXILIARY LOCK
Up Stream Gate/Down Stream Side

ISLAND WALL LEAF

	Quoin (Island Wall)				7.0 Feet				12.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.609	0.600	0.579	0.021	0.963	0.879	0.733	0.146	1.070	0.911	0.803	0.108
3	0.859	0.741	0.643	0.098	0.954	0.863	0.714	0.149	1.147	0.999	0.798	0.201
6	0.999	0.916	0.736	0.180	1.006	0.903	0.733	0.170	1.283	1.014	0.803	0.211
9	1.063	0.903	0.765	0.138	1.074	0.928	0.747	0.181	1.250	1.019	0.821	0.198
12	1.234	1.016	0.758	0.258	1.186	0.943	0.752	0.191	1.336	1.024	0.816	0.208
15	1.392	1.022	0.766	0.256	1.358	0.983	0.755	0.228	1.497	1.016	0.800	0.216
18	1.618	1.033	0.789	0.244	1.499	0.973	0.736	0.237	1.662	1.036	0.788	0.248
21	1.799	1.046	0.749	0.297	1.638	0.985	0.711	0.274	1.648	1.014	0.756	0.258
24	2.231	1.021	0.785	0.236	1.818	0.984	0.692	0.292	1.917	1.030	0.738	0.292
27	2.117	1.003	0.638	0.365	1.740	0.979	0.669	0.310	1.883	1.019	0.722	0.297

	19.0 Feet				25.0 Feet				37.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.098	0.989	0.816	0.173	1.126	0.940	0.809	0.131	1.171	1.023	0.836	0.187
3	1.202	0.996	0.817	0.179	1.210	0.986	0.802	0.184	1.313	1.031	0.849	0.182
6	1.240	1.026	0.825	0.201	1.278	1.016	0.817	0.199	1.398	1.070	0.861	0.209
9	1.295	1.033	0.827	0.206	1.315	1.033	0.840	0.193	1.435	1.086	0.864	0.222
12	1.388	1.057	0.816	0.241	1.516	1.059	0.839	0.220	1.593	1.093	0.863	0.230
15	1.492	1.050	0.819	0.231	1.699	1.078	0.847	0.231	1.734	1.113	0.866	0.247
18	1.779	1.055	0.801	0.254	1.942	1.092	0.828	0.264	1.965	1.102	0.850	0.252
21	1.900	1.051	0.787	0.264	2.147	1.087	0.816	0.271	2.367	1.116	0.834	0.282
24	2.271	1.063	0.774	0.289	2.399	1.096	0.808	0.288	2.586	1.120	0.829	0.291
27	1.780	1.064	0.760	0.304	2.056	1.089	0.795	0.294	2.667	1.127	0.823	0.304

	50.0 Feet				56.0 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.188	0.986	0.830	0.156	0.960	0.856	0.737	0.119
3	1.305	1.035	0.841	0.194	1.318	1.008	0.795	0.213
6	1.405	1.065	0.860	0.205	1.399	1.059	0.841	0.218
9	1.434	1.080	0.866	0.214	1.524	1.072	0.866	0.206
12	1.583	1.100	0.862	0.238	1.683	1.083	0.863	0.220
15	1.816	1.100	0.855	0.245	1.887	1.100	0.860	0.240
18	2.057	1.103	0.848	0.255	2.385	1.123	0.830	0.293
21	2.300	1.133	0.833	0.300	2.520	1.117	0.807	0.310
24	2.617	1.142	0.812	0.330	2.645	1.113	0.787	0.326
27	2.520	1.135	0.807	0.328	2.800	1.115	0.772	0.343

Miter

DEPTH	ON	OFF	DECAY	DELTA
Bottom	0.940	0.799	0.502	0.297
3	0.910	0.808	0.701	0.107
6	1.000	0.912	0.760	0.152
9	1.167	0.959	0.759	0.200
12	1.322	1.018	0.806	0.212
15	1.473	1.057	0.811	0.246
18	1.543	1.048	0.802	0.246
21	1.892	1.118	0.779	0.339
24	2.055	1.107	0.738	0.369
27	1.905	1.059	0.660	0.399

PIKE ISLAND AUXILIARY LOCK
Up Stream Gate/Down Stream Side

LAND WALL LEAF

	56.0 Feet				50.0 Feet				37.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.107	0.894	0.730	0.164	1.011	0.906	0.750	0.156	1.061	0.921	0.758	0.163
3	1.149	0.958	0.732	0.226	1.096	0.933	0.730	0.203	1.188	0.991	0.742	0.249
6	1.234	1.002	0.762	0.240	1.149	0.967	0.722	0.245	1.118	0.976	0.723	0.253
9	1.326	1.023	0.779	0.244	1.170	0.968	0.726	0.242	1.141	0.967	0.718	0.249
12	1.495	1.072	0.802	0.270	1.355	1.020	0.757	0.263	1.356	0.992	0.732	0.260
15	1.687	1.072	0.798	0.274	1.501	1.047	0.764	0.283	1.491	1.026	0.734	0.292
18	1.971	1.056	0.769	0.287	1.843	1.051	0.765	0.286	1.711	1.031	0.745	0.286
21	2.379	1.094	0.774	0.320	1.993	1.044	0.742	0.302	1.903	1.041	0.733	0.308
24	2.699	1.095	0.759	0.336	2.110	1.056	0.726	0.330	2.066	1.057	0.727	0.330
27	2.101	1.078	0.724	0.354	1.789	1.036	0.708	0.328	1.722	1.032	0.707	0.325

	25.0 Feet				19.0 Feet				12.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.019	0.921	0.767	0.154	0.994	0.892	0.762	0.130	0.983	0.901	0.768	0.133
3	1.148	0.961	0.716	0.245	1.005	0.902	0.723	0.179	1.052	0.899	0.726	0.173
6	1.112	0.955	0.707	0.248	0.993	0.884	0.695	0.189	1.086	0.928	0.715	0.213
9	1.163	0.958	0.718	0.240	1.051	0.917	0.695	0.222	1.114	0.928	0.717	0.211
12	1.486	1.006	0.723	0.283	1.184	0.945	0.699	0.246	1.290	0.964	0.703	0.261
15	1.566	1.002	0.714	0.288	1.242	0.939	0.685	0.254	1.428	0.984	0.694	0.290
18	1.699	1.006	0.708	0.298	1.327	0.955	0.680	0.275	1.621	0.970	0.676	0.294
21	1.734	1.008	0.695	0.313	1.394	0.954	0.663	0.291	1.672	0.981	0.663	0.318
24	1.775	0.996	0.692	0.304	1.521	0.966	0.660	0.306	1.726	0.984	0.635	0.349
27	1.600	1.003	0.676	0.327	1.348	0.934	0.646	0.288	1.376	0.918	0.611	0.307

	7.0 Feet				Quoin (Land Wall)			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.821	0.702	0.735	*****	0.654	0.638	0.534	0.104
3	0.818	0.762	0.676	0.086	1.079	0.805	0.622	0.183
6	0.818	0.746	0.652	0.094	0.935	0.760	0.662	0.098
9	0.905	0.796	0.654	0.142	0.840	0.716	0.611	0.105
12	1.027	0.829	0.672	0.157	0.963	0.796	0.618	0.178
15	1.130	0.867	0.652	0.215	0.987	0.865	0.624	0.241
18	1.307	0.893	0.648	0.245	1.143	0.831	0.573	0.258
21	1.448	0.873	0.620	0.253	1.499	0.850	0.565	0.285
24	1.574	0.892	0.589	0.303	2.158	0.888	0.528	0.360
27	1.409	0.856	0.570	0.286	1.787	0.887	0.419	0.468

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Up Stream Side

ISLAND WALL LEAF

	Quoin (Island Wall)				Bevel				Between Bevel & Anode			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.040	0.945	0.804	0.141	1.119	0.962	0.820	0.142	1.072	0.957	0.824	0.133
3	0.927	0.818	0.660	0.158	1.149	0.965	0.815	0.150	1.097	0.969	0.827	0.142
6	1.088	0.941	0.800	0.141	1.290	1.015	0.835	0.180	1.240	0.981	0.819	0.162
9	1.326	1.041	0.854	0.187	1.436	1.057	0.857	0.200	1.342	0.999	0.815	0.184
12	1.540	1.083	0.864	0.219	1.633	1.097	0.853	0.244	1.399	1.013	0.819	0.194
15	1.524	1.086	0.856	0.230	1.724	1.104	0.843	0.261	1.440	1.029	0.812	0.217
18	1.431	1.030	0.829	0.201	1.690	1.137	0.842	0.295	1.457	1.039	0.810	0.221
21	1.560	1.068	0.809	0.259	1.735	1.102	0.883	0.219	1.581	1.035	0.805	0.230
24	1.735	1.082	0.812	0.270	1.999	1.104	0.836	0.268	1.647	1.011	0.790	0.229
27	1.899	1.100	0.807	0.293	2.276	1.076	0.811	0.265	1.830	1.020	0.784	0.236
30	2.299	1.108	0.797	0.311	2.489	1.068	0.805	0.263	1.947	1.021	0.775	0.246
33	2.530	1.103	0.772	0.331	2.704	1.064	0.785	0.279	1.961	1.017	0.768	0.249
36	2.470	1.094	0.750	0.344	3.280	1.105	0.765	0.340	1.999	1.021	0.756	0.265
39	2.434	1.099	0.728	0.371	2.566	1.086	0.755	0.331	1.899	1.012	0.753	0.259

	2nd Anode Column				Between Anode Columns				3rd Anode Column			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF*	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.073	0.947	0.776	0.171	1.052	0.780	0.759	0.021	1.038	0.915	0.744	0.171
3	1.066	0.941	0.777	0.164	1.051	0.787	0.756	0.031	1.023	0.920	0.743	0.177
6	1.252	0.933	0.771	0.162	1.201	0.776	0.753	0.023	1.175	0.908	0.748	0.160
9	1.229	0.935	0.760	0.175	1.189	0.762	0.742	0.020	1.178	0.911	0.729	0.182
12	1.238	0.945	0.758	0.187	1.133	0.748	0.732	0.016	1.165	0.923	0.722	0.201
15	1.252	0.958	0.760	0.198	1.022	0.720	0.724	*****	1.184	0.925	0.715	0.210
18	1.172	0.963	0.768	0.195	1.128	0.754	0.731	0.023	1.112	0.911	0.707	0.204
21	1.690	0.932	0.751	0.181	1.161	0.756	0.731	0.025	1.543	0.905	0.716	0.189
24	1.278	0.931	0.737	0.194	1.178	0.737	0.714	0.023	1.195	0.884	0.705	0.179
27	1.299	0.918	0.729	0.189	1.100	0.699	0.681	0.018	1.207	0.877	0.701	0.176
30	1.500	0.919	0.724	0.195	1.100	0.703	0.696	0.007	1.396	0.882	0.702	0.180
33	1.374	0.906	0.722	0.184	1.275	0.723	0.709	0.014	1.313	0.883	0.704	0.179
36	1.506	0.913	0.719	0.194	1.314	0.725	0.711	0.014	1.690	0.897	0.706	0.191
39	1.397	0.914	0.721	0.193	1.190	0.726	0.711	0.015	1.336	0.879	0.705	0.174

* The current interrupter was not functioning during this "OFF" column of data invalidating the "OFF" and "DELTA" data at this point on the gate.

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Up Stream Side

ISLAND WALL LEAF

	Between Anode Columns				4th Anode Column				Bevel			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.023	0.911	0.741	0.170	0.982	0.882	0.742	0.140	1.037	0.887	0.750	0.137
3	1.007	0.903	0.733	0.170	0.969	0.876	0.726	0.150	1.060	0.990	0.746	0.244
6	1.158	0.893	0.728	0.165	1.158	0.908	0.723	0.185	1.164	0.945	0.745	0.200
9	1.144	0.893	0.715	0.178	1.113	0.912	0.702	0.210	1.199	1.000	0.822	0.178
12	1.072	0.875	0.704	0.171	1.105	0.882	0.690	0.192	1.199	0.990	0.809	0.181
15	1.012	0.861	0.684	0.177	1.063	0.849	0.692	0.157	1.529	1.007	0.775	0.232
18	0.839	0.770	0.637	0.133	0.824	0.747	0.668	0.079	1.400	1.018	0.782	0.236
21	1.028	0.844	0.658	0.186	1.297	0.889	0.701	0.188	1.600	1.011	0.747	0.264
24	1.108	0.864	0.685	0.179	1.229	0.873	0.699	0.174	2.299	1.007	0.755	0.252
27	1.146	0.866	0.694	0.172	1.300	0.885	0.691	0.194	2.160	0.977	0.741	0.236
30	1.080	0.860	0.696	0.164	1.522	0.896	0.697	0.199	2.315	0.971	0.729	0.242
33	1.238	0.875	0.698	0.177	1.500	0.889	0.698	0.191	2.565	0.978	0.720	0.258
36	1.287	0.871	0.698	0.173	2.421	0.942	0.694	0.248	2.431	0.964	0.699	0.265
39	1.294	0.873	0.697	0.176	1.440	0.904	0.686	0.218	1.851	0.936	0.652	0.284

Miter

DEPTH	ON	OFF	DECAY	DELTA
Bottom	1.041	0.885	0.750	0.135
3	1.033	0.898	0.753	0.145
6	1.189	0.947	0.767	0.180
9	1.271	0.993	0.780	0.213
12	1.343	1.002	0.779	0.223
15	1.318	0.963	0.763	0.200
18	1.113	0.834	0.730	0.104
21	1.069	0.836	0.687	0.149
24	1.466	0.927	0.706	0.221
27	1.655	0.965	0.711	0.254
30	1.894	0.951	0.703	0.248
33	1.727	0.930	0.704	0.226
36	1.600	0.903	0.691	0.212

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Up Stream Side

LAND WALL LEAF

DEPTH	Bevel ON	Bevel OFF	Bevel DECAY	Bevel DELTA	4th Anode Column ON	4th Anode Column OFF	4th Anode Column DECAY	4th Anode Column DELTA	Between Anode Columns ON	Between Anode Columns OFF	Between Anode Columns DECAY	Between Anode Columns DELTA
Bottom	1.043	0.865	0.753	0.112	1.007	0.877	0.754	0.123	0.965	0.865	0.764	0.101
3	1.072	0.897	0.756	0.141	0.966	0.864	0.749	0.115	0.950	0.866	0.768	0.098
6	1.299	0.963	0.790	0.173	0.999	0.887	0.745	0.142	1.109	0.883	0.749	0.134
9	1.239	1.000	0.771	0.229	1.068	0.870	0.729	0.141	1.135	0.877	0.734	0.143
12	1.503	0.999	0.787	0.212	1.039	0.866	0.705	0.161	1.054	0.867	0.719	0.148
15	1.489	1.005	0.760	0.245	1.138	0.888	0.688	0.200	1.006	0.861	0.698	0.163
18	1.399	1.047	0.733	0.314	0.896	0.820	0.613	0.207	0.836	0.777	0.653	0.124
21	1.348	1.034	0.733	0.301	1.200	0.896	0.701	0.195	0.950	0.814	0.682	0.132
24	1.799	0.996	0.746	0.250	1.257	0.892	0.699	0.193	1.109	0.860	0.700	0.160
27	2.020	0.989	0.734	0.255	1.317	0.909	0.705	0.204	1.184	0.881	0.708	0.173
30	2.600	1.011	0.733	0.278	1.463	0.915	0.708	0.207	1.240	0.885	0.685	0.200
33	2.215	0.992	0.731	0.261	1.478	0.909	0.707	0.202	1.283	0.892	0.704	0.188
36	1.684	0.937	0.720	0.217	2.004	0.906	0.700	0.206	1.315	0.899	0.705	0.194
39	1.399	0.890	0.709	0.181	1.419	0.909	0.684	0.225	1.322	0.894	0.705	0.189

DEPTH	3rd Anode Columns ON	3rd Anode Columns OFF	3rd Anode Columns DECAY	3rd Anode Columns DELTA	Between Anode Columns ON	Between Anode Columns OFF	Between Anode Columns DECAY	Between Anode Columns DELTA	2nd Anode Column ON	2nd Anode Column OFF	2nd Anode Column DECAY	2nd Anode Column DELTA
Bottom	0.964	0.870	0.768	0.102	0.980	0.882	0.780	0.102	1.053	0.935	0.796	0.139
3	0.990	0.888	0.777	0.111	0.999	0.904	0.787	0.117	1.049	0.938	0.798	0.140
6	1.162	0.903	0.764	0.139	1.172	0.919	0.776	0.143	1.199	0.951	0.790	0.161
9	1.165	0.907	0.753	0.154	1.177	0.915	0.762	0.153	1.225	0.941	0.781	0.160
12	1.147	0.899	0.746	0.153	1.137	0.913	0.748	0.165	1.200	0.945	0.774	0.171
15	1.163	0.901	0.744	0.157	1.078	0.901	0.720	0.181	1.216	0.969	0.777	0.192
18	0.954	0.848	0.743	0.105	0.999	0.887	0.754	0.133	1.163	0.957	0.787	0.170
21	1.194	0.880	0.732	0.148	1.086	0.902	0.756	0.146	1.367	0.944	0.780	0.164
24	1.157	0.876	0.723	0.153	1.147	0.907	0.737	0.170	1.263	0.925	0.760	0.165
27	1.192	0.884	0.718	0.166	1.112	0.914	0.699	0.215	1.290	0.924	0.749	0.175
30	1.399	0.897	0.714	0.183	1.173	0.917	0.703	0.214	1.460	0.926	0.743	0.183
33	1.313	0.894	0.716	0.178	1.272	0.912	0.723	0.189	1.373	0.921	0.743	0.178
36	1.483	0.902	0.716	0.186	1.301	0.920	0.725	0.195	1.565	0.926	0.740	0.186
39	1.337	0.892	0.718	0.174	1.307	0.901	0.726	0.175	1.368	0.923	0.738	0.185

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Up Stream Side

LAND WALL LEAF

	Between Anode & Bevel				Quoin (Land Wall)				Bevel			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.211	0.991	0.836	0.155	1.173	0.996	0.829	0.167	1.160	1.005	0.838	0.167
3	1.224	0.999	0.835	0.164	1.016	0.871	0.818	0.053	1.190	1.030	0.829	0.201
6	1.322	1.013	0.853	0.160	1.426	1.022	0.823	0.199	1.433	1.038	0.860	0.178
9	1.445	1.031	0.852	0.179	1.566	1.074	0.875	0.199	1.701	1.058	0.886	0.172
12	1.499	1.038	0.850	0.188	1.595	1.089	0.897	0.192	1.693	1.068	0.884	0.184
15	1.532	1.045	0.846	0.199	1.700	1.071	0.891	0.180	1.726	1.066	0.873	0.193
18	1.594	1.040	0.840	0.200	1.690	1.047	0.866	0.181	1.800	1.061	0.867	0.194
21	1.671	1.033	0.835	0.198	1.766	1.064	0.858	0.206	1.836	1.065	0.869	0.196
24	1.689	1.018	0.820	0.198	1.809	1.071	0.862	0.209	1.935	1.064	0.865	0.199
27	1.723	1.009	0.813	0.196	1.914	1.065	0.857	0.208	1.989	1.054	0.839	0.215
30	1.807	1.011	0.802	0.209	2.021	1.065	0.847	0.218	2.148	1.037	0.830	0.207
33	1.790	0.998	0.795	0.203	1.924	1.038	0.832	0.206	2.200	1.025	0.827	0.198
36	1.739	1.002	0.789	0.213	1.672	1.002	0.816	0.187	1.899	1.025	0.808	0.217
39	1.698	0.990	0.786	0.204	1.580	0.997	0.805	0.192	1.738	1.013	0.801	0.212

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Down Stream Side

ISLAND WALL LEAF

	Quoin (Island Wall)				7.0 Feet				12.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	0.842	0.789	0.769	0.020	1.285	1.019	0.787	0.232	1.311	1.085	0.898	0.187
3	1.799	1.027	0.738	0.289	1.180	1.002	0.790	0.212	1.600	1.075	0.868	0.207
6	1.650	0.995	0.757	0.238	1.198	1.003	0.785	0.218	1.538	1.085	0.859	0.226
9	1.351	1.011	0.730	0.281	1.265	1.003	0.762	0.241	1.572	1.077	0.843	0.234
12	1.245	0.976	0.694	0.282	1.278	1.001	0.746	0.255	1.578	1.078	0.801	0.277
15	1.263	0.914	0.602	0.312	1.328	0.997	0.685	0.312	1.541	1.065	0.751	0.314

	19.0 Feet				25.0 Feet				37.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.352	1.036	0.866	0.170	1.320	1.066	0.859	0.207	1.387	1.095	0.869	0.226
3	1.383	1.076	0.849	0.227	1.507	1.092	0.861	0.231	1.650	1.110	0.854	0.256
6	1.465	1.092	0.846	0.246	1.599	1.093	0.855	0.238	1.699	1.118	0.840	0.278
9	1.521	1.091	0.829	0.262	1.613	1.097	0.850	0.247	1.770	1.112	0.833	0.279
12	1.554	1.095	0.802	0.293	1.721	1.104	0.825	0.279	1.690	1.106	0.813	0.293
15	1.541	1.084	0.755	0.329	1.780	1.102	0.738	0.364	1.599	1.110	0.751	0.359

	50.0 Feet				56.0 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.296	1.036	0.885	0.151	1.414	1.058	0.788	0.270
3	1.641	1.093	0.881	0.212	1.512	1.060	0.871	0.189
6	1.689	1.115	0.863	0.252	1.799	1.097	0.876	0.221
9	1.619	1.123	0.847	0.276	1.846	1.109	0.864	0.268
12	1.629	1.111	0.834	0.277	1.754	1.109	0.841	0.268
15	1.599	1.100	0.767	0.333	1.726	1.114	0.770	0.344

Miter

DEPTH	ON	OFF	DECAY	DELTA
Bottom	1.275	0.976	0.697	0.279
3	1.234	1.016	0.791	0.225
6	1.536	1.074	0.847	0.227
9	1.444	1.099	0.848	0.251
12	1.440	1.088	0.825	0.263
15	1.531	1.070	0.754	0.316

PIKE ISLAND AUXILIARY LOCK
Down Stream Gate/Down Stream Side

LAND WALL SIDE

	56.0 Feet				50.0 Feet				37.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.092	0.887	0.747	0.140	1.368	1.054	0.875	0.179	1.304	1.068	0.942	0.126
3	1.850	1.052	0.863	0.189	1.491	1.096	0.874	0.222	1.491	1.087	0.902	0.185
6	1.759	1.107	0.884	0.223	1.452	1.098	0.882	0.216	1.563	1.098	0.883	0.215
9	1.858	1.117	0.869	0.248	1.493	1.115	0.881	0.234	1.563	1.102	0.887	0.215
12	1.709	1.101	0.856	0.245	1.563	1.108	0.852	0.256	1.550	1.105	0.867	0.238
15	1.549	1.080	0.767	0.313	1.538	1.087	0.782	0.305	1.399	1.064	0.811	0.253

	25.0 Feet				19.0 Feet				12.5 Feet			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.270	1.041	0.884	0.157	1.304	1.049	0.887	0.162	1.308	1.065	0.898	0.167
3	1.380	1.071	0.890	0.181	1.361	1.065	0.881	0.184	1.500	1.090	0.905	0.185
6	1.540	1.109	0.877	0.232	1.464	1.082	0.871	0.211	1.600	1.088	0.868	0.220
9	1.360	1.102	0.876	0.226	1.491	1.090	0.856	0.234	1.584	1.089	0.851	0.238
12	1.638	1.104	0.852	0.252	1.508	1.086	0.827	0.259	1.561	1.065	0.822	0.243
15	1.429	1.066	0.807	0.259	1.499	1.071	0.778	0.293	1.415	1.037	0.749	0.288

	7.0 Feet				Quoin (Land Wall)			
DEPTH	ON	OFF	DECAY	DELTA	ON	OFF	DECAY	DELTA
Bottom	1.278	1.027	0.875	0.152	0.906	0.810	0.778	0.032
3	1.283	1.016	0.839	0.177	1.297	0.955	0.812	0.143
6	1.277	1.000	0.802	0.198	1.241	0.957	0.773	0.184
9	1.267	1.006	0.771	0.235	1.238	1.008	0.759	0.249
12	1.264	1.007	0.746	0.261	1.300	0.994	0.717	0.277
15	1.384	1.025	0.713	0.312	1.000	0.954	0.616	0.338

PIKE ISLAND RECTIFIER
(RIVER WALL - USG)

8/21/89

Manufacturer: Goodall

Model: TIAYCD 24-40/30/16/GGNPSZ

Type: 0031451 - 4 Circuits

Serial Number: 86A1084

Primary: 480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C

Output: 24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2	CIRCUIT #3	CIRCUIT #4
25.87 Volts 12.78 Amperes	17.80 Volts 6.00 Amperes	17.73 Volts 2.71 Amperes	9.78 Volts 0.68 Amperes

TERMINAL BOX DATA

Anode String		Anode String		Anode String		Anode Disk	
EAR No	Amperes	EAR No	Amperes	EAR No	Amperes	LSA No	Amperes
E2	1.60	A2	0.80	A1	0.15	1	0.045
F2	1.60	B2	0.70	B1	0.19	2	0.045
G2	1.50	C2	0.70	C1	0.17	3	0.045
H2	1.70	D2	0.70	D1	0.14	4	0.045
I2	1.60	M2	0.80	E1	0.16	5	0.045
J2	1.50	N2	0.80	F1	0.18	6	0.045
K2	1.70	O2	0.70	G1	0.14	7	0.045
L2	1.50	P2	0.70	H1	0.18	8	0.045
				I1	0.16	9	0.045
				J1	0.19	10	0.045
				K1	0.17	11	0.045
				L1	0.20	12	0.045
				M1	0.18	13	0.045
				N1	0.17	14	0.045
				O1	0.12	15	0.045
				P1	0.21		

PIKE ISLAND RECTIFIER
(LAND WALL - USG)
8/21/89

Manufacturer: Goodall

Model: CSAWSD - 24/30
HNPSE - 24/16

Type: 0031449

Serial Number: 86C1951 - 2 Circuits

Primary: 480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C

Output: 24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
28.55 Volts	5.12 Volts
23.52 Amperes	0.56 Amperes

TERMINAL BOX DATA

Anode String

EAR No.	Amperes
A	3.19
B	2.72
C	2.95
D	3.04
E	2.78
F	3.00
G	3.04
H	2.81

Anode Disk

LSA No.	Amperes
1	0.037
2	0.037
3	0.037
4	0.037
5	0.037
6	0.037
7	0.037
8	0.037
9	0.037
10	0.037
11	0.037
12	0.037
13	0.037
14	0.037
15	0.037

PIKE ISLAND RECTIFIER
(RIVER WALL- DSG)
8/21/89

Manufacturer: Goodall

Model: CSAWSD - 24/30
HNPSE - 24/16

Type: 0031449 - 2 Circuits

Serial Number: 86C1950

Primary: 480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C

Output: 24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
28.61 Volts	5.22 Volts
24.84 Amperes	0.48 Amperes

TERMINAL BOX DATA

Anode String

EAR No.	Amperes
A	2.40
B	2.50
C	2.40
D	2.30
E	2.20
F	3.30
G	3.20
H	2.70

Anode Disk

LSA No.	Amperes
1	0.021
2	0.021
3	0.021
4	0.021
5	0.021
6	0.021
7	0.021
8	0.021
9	0.021
10	0.021
11	0.021
12	0.021
13	0.021
14	0.021
15	0.021
16	0.021
17	0.021
18	0.021
19	0.021
20	0.021
21	0.021
22	0.021
23	0.021

PIKE ISLAND RECTIFIER
(LAND WALL- DSG)
8/21/89

Manufacturer: Goodall

Model: CSAWSD - 24/30
HNPSE - 24/16

Type: 0031449 - 2 Circuits

Serial Number: 86C1949

Primary: 480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C

Output: 24/24 Volts, 3/16 Amperes

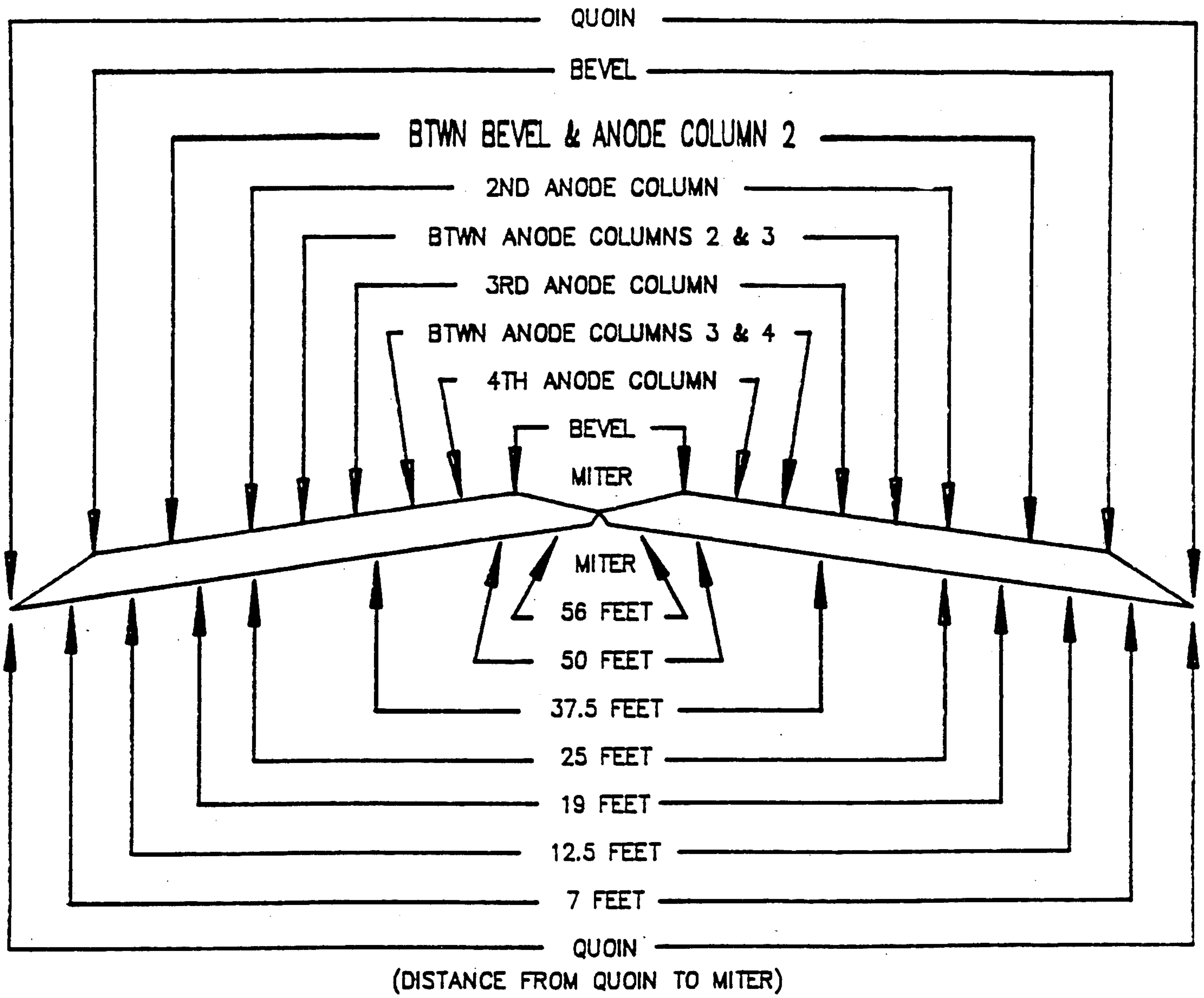
OPERATING DATA

CIRCUIT #1	CIRCUIT #2
28.18 Volts	5.14 Volts
24.72 Amperes	0.48 Amperes

TERMINAL BOX DATA

Anode String		Anode Disk	
EAR No.	Amperes	LSA No.	Amperes
A	2.20	1	0.021
B	2.40	2	0.021
C	2.70	3	0.021
D	2.20	4	0.021
E	2.30	5	0.021
F	2.80	6	0.021
G	3.10	7	0.021
H	2.70	8	0.021
		9	0.021
		10	0.021
		11	0.021
		12	0.021
		13	0.021
		14	0.021
		15	0.021
		16	0.021
		17	0.021
		18	0.021
		19	0.021
		20	0.021
		21	0.021
		22	0.021
		23	0.021

APPENDIX D: Potential Survey Data of Pike Island, 1991 Data



PIKE ISLAND AUXILIARY LOCK

TOP VIEW OF MITER GATE
(DRAWING APPLIES TO UPPER & LOWER GATES)

REFERENCE CELL LOCATIONS
FOR POTENTIAL MEASUREMENTS

PIKE ISLAND AUXILIARY LOCK
USG/USS

ISLAND WALL LEAF

	Quoin (Island Wall)				Bevel				Between Bevel & Anode			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.558	0.540	0.545	0.610	0.910	0.826	0.843	0.832	0.928	0.939	0.857	0.838
3-Gate	0.909	0.822	0.839	0.905	0.872	0.811	0.824	0.833	0.933	0.841	0.862	0.846
6	1.104	0.940	0.967	1.059	0.970	0.852	0.871	0.897	1.175	0.907	0.942	0.907
9	1.279	1.050	1.010	1.056	1.070	0.931	0.960	0.997	1.283	0.952	1.006	0.951
12	1.427	1.060	1.101	1.067	1.187	1.988	1.036	1.015	1.297	0.984	1.038	0.976
15	1.535	1.088	1.143	1.118	1.325	1.034	1.085	1.030	1.391	1.003	1.064	0.995
18	1.622	1.101	1.160	1.109	1.445	1.052	1.115	1.056	1.497	1.023	1.082	1.006
21	1.677	1.093	1.163	1.185	1.513	1.083	1.150	1.073	1.464	1.035	1.094	1.008
24	1.774	1.102	1.172	1.067	1.495	1.067	1.134	1.044	1.447	1.027	1.092	0.994
27	1.852	1.099	1.185	0.938	1.474	1.087	1.155	1.061	1.491	1.027	1.087	0.979
30	1.902	1.087	1.185	1.504	1.080	1.154	***	1.078	0.998	1.023	***	***

	2nd Anode Column				Between Anode Columns				3rd Anode Column			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.065	0.886	0.917	0.862	0.987	0.837	0.863	0.803	0.951	0.812	0.838	0.790
3-Gate	1.041	0.887	0.912	0.871	0.980	0.837	0.846	0.799	0.925	0.800	0.820	0.824
6	1.240	0.931	0.960	0.922	1.247	0.883	0.907	0.850	1.187	0.859	0.888	0.967
9	1.687	1.020	1.105	0.970	1.725	0.951	1.024	0.918	1.567	0.944	1.007	0.923
12	1.323	0.953	1.006	0.943	1.265	0.975	1.045	0.942	1.281	0.934	0.994	0.932
15	1.318	0.957	1.008	0.948	1.252	0.962	1.023	0.943	1.298	0.937	1.000	0.983
18	1.599	0.979	0.975	1.021	1.303	0.955	1.010	0.949	1.513	0.960	1.003	0.962
21	1.444	0.980	1.035	0.970	1.291	0.961	1.015	0.956	1.448	0.967	1.031	0.950
24	1.328	0.970	1.023	0.961	1.251	0.974	1.024	0.962	1.327	0.959	1.012	0.971
27	1.415	0.978	1.028	0.988	1.239	0.988	1.035	0.972	1.416	0.968	1.017	0.983
30	1.600	1.025	1.080	1.000	1.286	0.980	1.040	0.962	1.611	0.989	1.059	***

	Between Anode Columns				4th Anode Column				Bevel			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.936	0.804	0.828	0.779	0.837	0.750	0.777	0.757	0.866	0.771	0.809	0.773
3-Gate	0.955	0.791	0.830	0.777	0.810	0.729	0.751	0.742	0.870	0.779	0.816	0.776
6	1.057	0.829	0.853	0.873	1.110	0.849	0.883	0.881	1.022	0.860	0.911	0.866
9	1.777	0.931	0.991	0.911	1.345	0.937	1.007	0.919	1.129	0.937	1.008	0.967
12	1.227	0.927	0.986	0.914	1.099	0.935	0.998	0.920	1.110	0.958	1.026	1.014
15	1.189	0.924	0.988	0.921	1.080	0.940	0.989	0.942	1.033	0.939	0.985	0.967
18	1.188	0.927	0.988	0.930	1.480	0.991	1.048	1.054	1.241	1.018	1.097	1.003
21	1.204	0.934	0.994	0.936	1.247	0.977	1.037	0.967	1.308	1.019	1.106	1.008
24	1.219	0.941	1.000	0.940	1.135	0.973	1.023	0.976	1.342	1.040	1.124	1.003
27	1.216	0.945	1.007	0.943	1.366	0.994	1.036	1.000	1.465	1.094	1.140	1.018
30	1.231	0.957	1.017	0.945	1.409	1.009	1.086	1.050	1.417	1.040	1.130	1.021

PIKE ISLAND AUXILIARY LOCK
USG/USS

Miter

DEPTH	ON	OFF	IOP[1]	IOP[2]
Sill	0.900	0.794	0.863	0.762
3-Gate	0.917	0.804	0.867	0.788
6	1.093	0.891	0.992	0.878
9	1.186	0.951	1.062	0.956
12	1.204	0.972	1.068	0.967
15	1.195	0.966	1.067	0.994
18	1.300	1.008	1.124	***
21	1.343	1.014	1.170	***
24	1.339	1.021	1.181	***
27	1.430	1.026	1.184	***
30	1.331	0.987	1.115	***

PIKE ISLAND AUXILIARY LOCK
USG/USS

LAND WALL LEAF

	Bevel				4th Anode Column				Between Anode Columns			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP
Sill	0.858	0.774	0.830	0.774	0.802	0.731	0.767	0.768	0.820	0.741	0.770	0.75
3-Gate	0.881	0.788	0.845	0.783	0.815	0.737	0.767	0.737	0.815	0.733	0.759	0.74
6	1.059	0.901	0.977	0.885	0.973	0.781	0.815	0.821	0.974	0.775	0.806	0.81
9	1.085	0.970	1.024	0.918	1.116	0.830	0.886	0.867	1.167	0.835	0.897	0.86
12	1.015	0.910	0.970	0.905	0.936	0.841	0.891	0.880	0.992	0.877	0.937	0.89
15	0.923	0.860	0.909	0.959	0.939	0.854	0.891	0.910	1.013	0.869	0.926	0.88
18	1.160	0.980	1.061	1.036	0.942	0.899	1.329	0.946	1.033	0.866	0.921	0.89
21	1.221	0.973	1.079	1.085	1.065	0.883	0.951	0.925	1.055	0.867	0.926	0.89
24	1.251	0.981	1.097	1.058	1.054	0.878	0.939	0.922	1.065	0.867	0.928	0.89
27	1.266	0.996	1.102	1.073	1.244	0.890	0.951	0.915	1.063	0.879	0.932	0.88
30	1.642	0.887	0.968	0.857	1.063	0.894	0.950	0.873	1.070	0.887	0.938	0.88

	3rd Anode Columns				Between Anode Columns				2nd Anode Column			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP
Sill	0.817	0.740	0.762	0.763	0.827	0.745	0.763	0.813	0.837	0.754	0.773	0.83
3-Gate	0.837	0.743	0.767	0.756	0.841	0.750	0.773	0.820	0.870	0.768	0.790	0.82
6	1.049	0.794	0.815	0.823	1.045	0.795	0.820	0.862	1.000	0.804	0.826	0.88
9	1.176	0.849	0.915	0.873	1.227	0.842	0.901	0.894	1.497	0.840	0.890	0.92
12	1.051	0.882	0.950	0.873	1.088	0.887	0.938	0.902	1.127	0.850	0.901	0.92
15	1.094	0.867	0.922	0.910	1.092	0.863	0.920	0.908	1.128	0.860	0.913	0.95
18	1.540	0.867	0.938	0.886	1.119	0.865	0.920	0.910	1.227	0.866	0.909	0.96
21	1.161	0.865	0.922	0.887	1.115	0.864	0.921	0.909	1.225	0.874	0.926	0.98
24	1.121	0.870	0.926	0.888	1.093	0.875	0.927	0.904	1.159	0.879	0.930	0.96
27	1.215	0.877	0.922	0.891	1.051	0.885	0.921	0.900	1.199	0.882	0.932	0.95
30	1.236	0.886	0.948	0.893	1.103	0.887	0.938	8.892	1.266	0.889	0.942	0.93

	Between Anode & Bevel				Bevel				Quoin (Land Wall)			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP
Sill	0.912	0.822	0.844	0.838	0.911	0.827	0.849	0.844	0.865	0.815	0.835	0.42
3-Gate	0.927	0.832	0.855	0.850	0.935	0.843	0.867	0.864	0.933	0.825	0.851	0.72
6	1.083	0.884	0.915	0.924	1.178	0.969	1.004	0.964	1.099	0.924	0.956	0.91
9	1.184	0.941	0.985	0.966	1.296	1.023	1.068	1.026	1.214	0.980	1.023	0.93
12	1.207	0.957	1.005	0.985	1.311	1.028	1.079	1.045	1.272	1.000	1.044	0.89
15	1.271	0.980	1.029	0.995	1.399	1.051	1.103	1.061	1.389	1.020	1.063	1.00
18	1.363	0.985	1.039	1.004	1.553	1.061	1.114	1.051	1.507	1.041	1.093	1.07
21	1.399	0.978	1.044	0.999	1.701	1.067	1.137	1.073	1.650	1.048	1.115	1.10
24	1.393	0.978	1.033	0.990	1.683	1.081	1.149	1.061	1.708	1.041	1.109	1.08
27	1.360	0.944	1.004	0.950	1.718	1.042	1.109	1.055	1.698	1.029	1.084	0.89
30	1.078	0.860	0.901	0.804	1.397	0.975	1.042	0.980	1.468	0.971	1.020	0.56

PIKE ISLAND AUXILIARY LOCK
USG/DSS

ISLAND WALL LEAF

DEPTH	Quoin (Island Wall) ON	OFF	IOP[1]	IOP[2]	7 Feet ON	OFF	IOP[1]	IOP[2]	12.5 Feet ON	OFF	IOP[1]	IOP[2]
Sill	0.593	0.587	0.586	0.697	0.977	0.892	0.914	0.920	1.138	0.983	1.020	0.995
3	1.000	0.753	0.786	0.856	0.932	0.859	0.869	0.895	1.267	1.012	1.060	0.998
6	1.177	0.933	0.971	0.964	1.008	0.902	0.934	0.903	1.277	1.021	1.072	1.002
9	1.400	1.050	1.101	0.950	1.109	0.959	1.004	0.945	1.290	1.043	1.104	1.003
12	1.449	1.034	1.078	1.002	1.215	0.989	1.040	0.973	1.381	1.047	1.107	1.022
15	1.673	1.090	1.154	1.080	1.436	1.012	1.083	0.992	1.617	1.063	1.141	1.044
18	2.621	1.137	1.314	1.098	1.746	1.011	1.121	1.008	2.039	1.067	1.184	1.054
21	2.634	1.119	1.341	1.085	1.953	1.025	1.162	1.020	2.639	1.036	1.179	1.058
24	3.506	1.109	1.470	1.114	2.363	1.026	1.230	1.037	2.582	1.057	1.264	1.065
27	3.500	1.124	1.521	1.120	2.399	1.041	1.279	1.054	2.593	1.061	1.329	1.083

DEPTH	19 Feet ON	OFF	IOP[1]	IOP[2]	25 Feet ON	OFF	IOP[1]	IOP[2]	37.5 Feet ON	OFF	^@IOP[1]	IOP[2]
Sill	1.181	0.991	1.039	0.997	1.199	1.000	1.050	0.985	1.015	0.800	0.874	1.027
3	1.282	1.030	1.086	1.007	1.305	1.022	1.085	1.008	1.055	0.822	0.900	1.061
6	1.302	1.043	1.111	1.024	1.368	1.054	1.118	1.021	1.101	0.850	0.929	1.073
9	1.328	1.076	1.133	1.029	1.312	1.058	1.119	1.033	1.156	0.881	0.965	1.085
12	1.435	1.070	1.137	1.037	1.391	1.077	1.146	1.049	1.228	0.935	1.015	1.092
15	1.607	1.077	1.159	1.057	1.746	1.090	1.179	1.087	1.331	1.033	1.099	1.118
18	2.047	1.080	1.219	1.079	2.123	1.101	1.215	1.113	1.458	1.027	1.150	1.140
21	2.121	1.060	1.260	1.094	2.463	1.110	1.276	1.124	1.426	1.091	1.157	1.170
24	2.413	1.056	1.263	1.103	2.866	1.102	1.317	1.136	1.477	1.108	1.175	1.188
27	2.070	1.054	1.230	1.085	2.612	1.111	1.311	1.125	1.767	1.114	1.214	1.201

DEPTH	50 Feet ON	OFF	IOP[1]	IOP[2]	56 Feet ON	OFF	IOP[1]	IOP[2]
Sill	1.267	0.999	1.083	1.027	1.165	0.951	1.020	0.976
3	1.356	1.035	1.108	1.061	1.400	1.024	1.102	1.052
6	1.466	1.078	1.160	1.082	1.507	1.070	1.166	1.097
9	1.447	1.086	1.172	1.091	1.594	1.100	1.206	1.108
12	1.535	1.117	1.200	1.112	1.846	1.119	1.256	1.137
15	1.937	1.120	1.252	1.141	2.329	1.136	1.339	1.173
18	2.143	1.123	1.289	1.161	2.545	1.140	1.430	1.218
21	2.509	1.142	1.355	1.185	2.976	1.188	1.533	1.257
24	3.077	1.133	1.458	1.220	4.120	1.168	1.683	1.301
27	3.172	1.159	1.516	1.254	3.945	1.151	1.689	1.296

PIKE ISLAND AUXILIARY LOCK
USG/DSS

Miter

DEPTH	ON	OFF	IOP[1]	IOP[2]
Sill	0.438	0.431	0.428	0.745
3	0.932	0.539	0.864	0.943
6	1.172	0.962	1.044	0.983
9	1.071	0.916	0.973	0.952
12	1.133	1.026	1.068	1.052
15	1.306	1.064	1.068	1.099
18	1.534	1.072	1.166	1.121
21	1.872	1.096	1.266	1.212
24	1.785	1.099	1.470	1.276
27	2.354	1.111	1.721	1.146

PIKE ISLAND AUXILIARY LOCK
USG/DSS

LAND WALL LEAF

	56 Feet				50 Feet				37.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.888	0.801	0.873	0.995	0.950	0.863	0.938	0.920	1.019	0.906	0.968	0.920
3	1.276	0.986	1.097	1.009	1.128	0.949	1.039	0.943	1.006	0.949	1.003	0.927
6	1.249	0.999	1.157	1.035	1.146	0.953	1.061	0.933	1.106	0.950	1.006	0.913
9	1.310	1.045	1.205	1.080	1.196	0.986	1.183	0.951	1.079	0.933	0.985	0.907
12	1.484	1.071	1.313	1.115	1.359	1.022	1.179	0.973	1.188	0.989	1.037	0.945
15	1.631	1.072	1.495	1.142	1.476	1.020	1.266	1.055	1.321	0.975	1.062	1.001
18	1.781	1.060	1.457	1.181	1.818	1.023	1.305	1.083	1.465	0.945	1.056	1.023
21	2.300	1.113	2.000	1.238	2.049	0.981	1.341	1.086	1.715	0.937	1.086	1.021
24	3.437	1.115	2.187	1.237	2.250	0.987	1.455	1.090	1.845	0.944	1.107	1.038
27	2.356	1.116	2.072	1.230	1.726	0.977	1.449	1.082	1.430	0.918	1.068	1.021

	25 Feet				19 Feet				12.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.961	0.872	0.914	0.914	0.940	0.869	0.895	0.910	0.946	0.855	0.886	0.906
3	1.139	0.927	0.975	0.917	0.949	0.864	0.897	0.897	1.106	0.923	0.957	0.891
6	1.076	0.930	0.968	0.928	0.924	0.840	0.879	0.895	1.050	0.903	0.933	0.906
9	1.100	0.955	0.994	0.930	0.943	0.860	0.891	0.888	1.059	0.926	0.961	0.895
12	1.196	0.960	1.003	0.940	1.069	0.911	0.951	0.933	1.083	0.902	0.930	0.941
15	1.240	0.956	1.020	0.999	1.083	0.880	0.930	0.955	1.300	0.945	0.991	0.953
18	1.395	0.927	0.993	0.995	1.133	0.867	0.924	0.948	1.291	0.900	0.951	0.970
21	1.443	0.900	0.986	0.986	1.194	0.853	0.934	0.938	1.360	0.877	0.945	0.961
24	1.676	0.906	1.009	0.981	1.275	0.855	0.954	0.950	1.690	0.873	0.978	0.983
27	1.369	0.901	0.997	0.949	1.145	0.935	0.920	0.924	1.230	0.802	0.876	0.916

	7 Feet				Quoin (Land Wall)			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.834	0.791	0.804	0.812	0.520	0.519	0.516	0.588
3	0.775	0.734	0.745	0.773	0.606	0.693	0.694	0.763
6	0.776	0.734	0.745	0.739	0.970	0.818	0.836	0.822
9	0.831	0.756	0.773	0.778	0.798	0.746	0.746	0.772
12	0.900	0.788	0.813	0.801	1.084	0.832	0.859	0.800
15	0.963	0.790	0.816	0.846	1.233	0.850	0.890	0.805
18	1.115	0.799	0.846	0.862	1.125	0.794	0.801	0.875
21	1.286	0.793	0.862	0.863	1.320	0.820	0.857	0.870
24	1.418	0.792	0.867	0.870	2.000	0.833	0.886	0.886
27	1.217	0.746	0.806	0.834	1.310	0.736	0.786	0.830

PIKE ISLAND AUXILIARY LOCK
DSG/USS

ISLAND WALL LEAF

DEPTH	Quoin (Island Wall) ON	OFF	IOP[1]	IOP[2]	Bevel ON	OFF	IOP[1]	IOP[2]	Between Bevel & Anode ON	OFF	IOP[1]	IOP[2]
Sill	1.100	0.971	1.025	0.905	1.127	0.980	1.027	0.994	1.157	0.978	1.038	1.00
3-Gate	1.110	0.930	0.980	0.995	1.147	0.975	1.027	1.000	1.162	0.990	1.047	1.01
6	1.374	1.039	1.097	1.076	1.326	1.019	1.083	1.060	1.280	0.997	1.054	1.03
9	1.571	1.085	1.166	1.115	1.526	1.052	1.140	1.085	1.433	1.005	1.086	1.05
12	1.648	1.162	1.194	1.131	1.635	1.069	1.172	1.112	1.470	1.018	1.108	1.06
15	1.681	1.096	1.196	1.120	1.702	1.079	1.195	1.121	1.501	1.039	1.131	1.08
18	1.645	1.080	1.177	1.114	1.677	1.091	2.214	1.131	1.463	1.043	1.144	1.09
21	1.685	1.080	1.179	1.126	1.675	1.089	1.196	1.120	1.493	1.053	1.143	1.09
24	2.024	1.094	1.237	1.161	1.911	1.078	1.201	1.128	1.691	1.032	1.147	1.08
27	2.332	1.099	1.282	1.196	2.256	1.068	1.232	1.144	1.789	1.028	1.155	1.09
30	2.704	1.104	1.355	1.226	2.696	1.059	1.264	1.148	1.984	1.013	1.170	1.09
33	2.990	1.082	1.406	1.150	2.856	1.062	1.292	1.166	2.144	1.015	1.191	1.10
36	3.049	1.083	1.431	1.245	2.999	1.059	1.331	1.195	2.220	1.008	1.205	1.12
39	3.048	1.066	1.420	***	2.900	1.047	1.340	1.180	2.184	1.023	1.234	1.12

DEPTH	2nd Anode Column ON	OFF	IOP[1]	IOP[2]	Between Anode Columns ON	OFF	IOP[1]	IOP[2]	3rd Anode Column ON	OFF	IOP[1]	IOP[2]
Sill	1.120	0.959	1.020	0.993	1.084	0.937	0.997	0.979	1.060	0.923	0.986	0.97
3-Gate	1.116	0.964	1.020	0.997	1.290	0.945	1.000	0.984	1.072	0.943	0.994	0.97
6	1.299	0.950	0.994	1.002	1.315	0.930	0.991	0.990	1.259	0.935	0.996	0.98
9	1.402	0.950	1.031	1.003	1.349	0.931	1.015	0.992	1.368	0.929	1.020	0.98
12	1.315	0.947	1.025	1.004	1.274	0.936	1.020	1.002	1.262	0.924	1.014	0.99
15	1.724	0.967	1.066	1.014	1.298	0.946	1.008	1.032	1.585	0.972	1.077	1.01
18	1.246	0.978	1.059	1.026	1.161	0.954	1.027	1.008	1.174	0.940	1.026	0.9
21	1.261	0.991	1.061	1.020	1.192	0.960	1.042	1.001	1.288	0.935	1.019	0.9
24	1.362	0.978	1.051	1.010	1.223	0.955	1.036	0.997	1.305	0.925	1.020	0.9
27	1.329	0.948	1.041	1.008	1.164	0.919	1.008	0.994	1.276	0.918	1.015	0.9
30	1.399	0.933	1.036	1.012	1.158	0.912	1.001	1.032	1.371	0.910	1.015	0.9
33	1.373	0.959	1.055	1.032	1.363	0.912	1.028	1.020	1.547	0.913	1.039	1.0
36	1.517	0.925	1.043	1.014	1.434	0.915	1.038	1.004	1.539	0.910	1.033	1.0
39	1.544	0.924	1.047	1.013	1.440	0.918	1.042	1.004	1.552	0.914	1.049	1.0

PIKE ISLAND AUXILIARY LOCK
DSG/USS

ISLAND WALL LEAF

	Between Anode Columns				4th Anode Column				Bevel			
DEPTH	ON	OFF	IOP1	IOP2	ON	OFF	IOP1	IOP2	ON	OFF	IOP1	IOP2
Sill	1.026	0.921	0.977	0.949	1.086	0.893	0.986	0.974	1.026	0.874	0.977	0.973
3-Gate	1.034	0.921	0.968	0.937	1.094	0.906	0.992	0.945	1.051	0.910	0.997	0.986
6	1.217	0.914	0.962	0.956	1.228	0.917	0.942	0.973	1.224	0.954	1.073	1.070
9	1.277	0.910	0.911	0.956	1.236	0.918	0.904	0.974	1.221	0.983	1.097	1.110
12	1.144	0.890	0.973	0.940	1.147	0.900	0.972	0.942	1.319	0.993	1.111	1.068
15	1.065	0.877	0.950	0.913	2.350	0.927	1.074	0.927	1.327	0.964	1.091	1.045
18	0.805	0.777	0.789	0.792	0.939	0.814	0.863	0.801	1.270	0.956	1.067	1.034
21	0.977	0.845	0.897	0.868	0.990	0.842	0.857	0.856	1.029	0.936	0.981	1.035
24	1.142	0.894	0.985	0.938	1.308	0.940	1.035	0.966	1.530	1.003	1.132	1.091
27	1.202	0.901	1.014	0.974	1.357	0.925	1.068	1.003	1.826	0.972	1.204	1.143
30	1.201	0.906	1.035	1.000	1.459	0.931	1.083	1.027	2.017	0.971	1.236	1.141
33	1.256	0.948	1.080	1.046	1.245	0.930	1.125	1.054	2.199	0.974	1.270	1.170
36	1.385	0.917	1.073	1.014	1.757	0.921	1.015	1.061	2.237	0.960	1.272	1.180
39	1.425	0.915	1.084	1.020	1.676	0.972	1.211	1.129	2.098	0.957	1.266	1.150

	Miter			
DEPTH	ON	OFF	IOP1	IOP2
Sill	1.082	0.808	1.023	1.103
3-Gate	1.129	0.914	1.061	1.220
6	1.178	0.948	1.097	1.272
9	1.341	0.988	1.229	1.279
12	1.410	1.014	1.290	1.240
15	1.410	1.013	1.308	***
18	1.317	0.961	1.211	***
21	1.194	0.897	1.097	***
24	1.249	0.945	1.411	***
27	1.662	0.998	1.437	***
30	1.883	1.057	1.595	***
33	2.031	1.086	1.067	***
36	2.053	0.987	1.628	***
39	1.938	0.946	1.490	***

The numbers in the last column were taken under turbulent conditions and are therefore not reliable.

PIKE ISLAND AUXILIARY LOCK
DSG/USS

LAND WALL LEAF

	Bevel				4th Anode Column				Between Anode Columns			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.077	0.856	1.020	0.973	1.081	0.908	1.030	0.939	1.010	0.882	0.960	0.936
3-Gate	1.104	0.902	1.021	0.983	1.076	0.912	1.019	0.937	0.991	0.884	0.934	0.932
6	1.162	0.939	1.050	1.036	1.220	0.951	1.073	0.956	1.142	0.890	0.961	0.951
9	1.437	1.016	1.173	1.097	1.473	1.021	1.191	0.965	1.269	0.884	0.978	0.951
12	1.315	0.999	1.135	1.062	1.041	0.902	0.923	0.957	1.118	0.869	0.960	0.938
15	1.357	0.971	1.114	1.073	1.342	0.975	1.062	0.974	1.050	0.857	0.938	0.914
18	1.280	0.993	1.117	1.039	1.028	0.869	0.944	0.867	0.919	0.806	0.862	0.820
21	1.023	0.949	0.991	1.045	1.001	0.910	0.945	0.892	0.845	0.779	0.810	0.815
24	1.325	1.013	1.137	1.096	1.254	0.931	1.055	0.978	1.111	0.861	0.962	0.921
27	2.678	0.993	1.220	1.143	1.302	0.923	1.085	1.018	1.224	0.889	1.018	0.966
30	2.944	0.971	1.291	1.184	1.371	0.924	1.094	1.055	1.284	0.896	1.044	0.992
33	1.326	0.955	1.215	1.199	1.700	0.914	1.143	1.067	1.342	0.899	1.063	1.004
36	1.905	0.938	1.335	1.200	1.623	0.904	1.143	1.080	1.381	0.991	1.075	1.014
39	1.736	0.917	1.321	1.162	1.626	0.902	1.172	1.100	1.395	0.886	1.087	1.020

	3rd Anode Columns				Between Anode Columns				2nd Anode Column			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.042	0.870	0.961	0.973	1.062	0.915	0.979	0.969	1.085	0.941	0.998	1.003
3-Gate	1.075	0.906	0.974	0.968	1.050	0.925	0.973	0.973	1.087	0.959	1.003	1.003
6	1.241	0.920	0.977	0.967	1.288	0.933	0.997	0.985	1.232	0.955	1.026	1.014
9	1.303	0.930	1.027	0.973	1.333	0.927	1.015	0.985	1.420	0.956	1.051	1.020
12	1.225	0.896	0.985	0.961	1.200	0.916	1.004	0.988	1.273	0.952	1.038	1.015
15	1.485	0.909	1.013	0.961	1.086	0.887	0.977	0.068	1.716	1.006	1.098	1.085
18	1.059	0.863	0.932	0.867	1.040	0.884	0.948	0.903	1.228	0.963	1.047	1.014
21	0.944	0.833	0.868	0.879	1.029	0.881	0.928	0.915	1.250	0.987	1.041	1.009
24	1.243	0.918	0.997	0.939	1.171	0.913	0.995	0.954	1.462	0.946	1.044	1.007
27	1.213	0.898	0.995	0.958	1.133	0.917	1.003	0.991	1.347	0.931	1.038	1.004
30	1.818	0.890	1.004	0.979	1.091	0.891	0.980	1.007	1.436	0.928	1.038	1.009
33	1.721	0.899	1.028	0.996	1.296	0.908	1.028	1.001	1.680	0.928	1.061	1.019
36	1.477	0.898	1.032	0.998	1.391	0.903	1.039	1.002	1.545	0.928	1.048	1.001
39	1.549	0.902	1.051	1.003	1.418	0.901	1.045	1.004	1.586	0.925	1.074	1.039

	Between Anode & Bevel				Quoin (Land Wall)				Bevel			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.234	0.996	1.073	1.056	1.294	1.034	1.102	0.954	1.209	1.029	1.085	0.995
3-Gate	1.237	1.025	1.081	1.059	1.293	1.043	1.097	1.026	1.238	1.032	1.091	1.108
6	1.317	1.040	1.102	1.074	1.304	0.928	0.978	1.108	1.423	1.050	1.097	1.121
9	1.529	1.037	1.129	1.089	1.632	1.094	1.139	1.144	1.900	1.129	1.178	1.144
12	1.557	1.043	1.144	1.103	1.732	1.131	1.214	1.150	1.927	1.090	1.227	1.163
15	1.579	1.061	1.172	1.115	1.847	1.132	1.242	1.149	1.987	1.116	1.257	1.166
18	1.593	1.062	1.179	1.114	1.842	1.131	1.246	1.130	2.020	1.106	1.258	1.158
21	1.591	1.073	1.173	1.109	1.841	1.105	1.217	1.124	2.026	1.107	1.253	1.149
24	1.771	1.052	1.179	1.109	1.750	1.094	1.203	1.125	2.176	1.090	1.260	1.153
27	1.814	1.043	1.184	1.106	1.900	1.100	1.225	1.160	2.383	1.101	1.284	1.155
30	1.913	1.039	1.189	1.108	2.085	1.113	1.269	1.179	2.500	1.098	1.279	1.154
33	2.017	1.039	1.196	1.101	2.152	1.114	1.274	1.166	2.758	1.080	1.307	1.138
36	2.017	1.041	1.212	1.102	2.287	1.116	1.325	1.30	2.677	1.068	1.298	1.125
39	2.080	1.028	1.205	***	2.391	1.102	1.354	***	2.616	1.069	1.308	***

PIKE ISLAND AUXILIARY LOCK
DSG/DSS

ISLAND WALL LEAF

	Quoin (Island Wall)				7 Feet				12.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.914	0.839	0.815	0.841	1.063	0.991	1.000	1.025	1.259	1.063	1.095	1.066
3	1.455	0.994	0.873	0.895	1.094	0.975	0.991	1.045	1.448	1.077	1.116	1.085
6	1.450	0.990	1.076	0.949	1.140	0.985	1.015	1.050	1.486	1.087	1.147	1.120
9	1.549	1.000	1.092	1.003	1.198	0.982	1.037	1.062	1.526	1.069	1.144	1.107
12	1.355	0.998	1.017	1.004	1.203	0.963	1.014	1.060	1.600	1.043	1.140	1.098
15	0.775	0.684	0.705	1.032	1.142	0.909	0.965	1.020	1.481	1.008	1.086	1.061
18	0.564	0.562	0.557	***	0.934	0.792	0.826	***	0.927	0.818	0.851	***

	19 Feet				25 Feet				37.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.258	1.074	1.118	1.098	1.326	1.037	1.101	1.113	1.395	1.081	1.166	1.154
3	1.345	1.062	1.259	1.112	1.509	1.072	1.162	1.120	1.590	1.092	1.196	1.163
6	1.377	1.060	1.141	1.125	1.588	1.084	1.179	1.126	1.721	1.091	1.214	1.166
9	1.397	1.058	1.131	1.116	1.549	1.063	1.160	1.141	1.702	1.083	1.195	1.155
12	1.385	1.032	1.120	1.106	1.598	1.049	1.144	1.127	1.738	1.066	1.179	1.148
15	1.285	0.998	1.068	1.086	1.599	1.018	1.125	1.120	1.573	1.040	1.188	1.132
18	1.019	0.879	0.921	***	1.072	0.897	0.949	***	1.052	0.894	0.951	***

	50 Feet				56 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.497	1.029	1.185	1.143	1.192	0.985	1.097	1.125
3	1.511	1.064	1.195	1.171	1.449	1.045	1.258	1.182
6	1.700	1.081	1.231	1.185	1.596	1.084	1.345	1.220
9	1.861	1.100	1.250	1.180	1.569	1.071	1.347	1.225
12	1.609	1.071	1.207	1.171	1.422	1.019	1.273	1.207
15	1.571	1.040	1.155	1.152	1.227	0.915	1.112	1.186
18	1.070	0.882	0.956	***	0.924	0.791	0.867	***

PIKE ISLAND AUXILIARY LOCK
DSG/DSS

ISLAND WALL\LAND WALL LEAVES MITER

Miter

DEPTH	ON	OFF	IOP[1]	IOP[2]
Sill	1.347	1.009	1.201	1.103
3	1.655	1.046	1.317	1.220
6	1.606	1.065	1.359	1.272
9	1.591	1.050	1.363	1.279
12	1.445	1.005	1.285	1.240
15	1.278	0.930	1.129	***
18	0.827	0.756	0.840	***

The numbers in the last column were taken under turbulent conditions and are therefore not reliable.

PIKE ISLAND AUXILIARY LOCK
DSG/DSS

LAND WALL SIDE

	56 Feet				50 Feet				37.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.251	1.115	1.186	1.160	1.280	1.036	1.148	1.140	1.215	1.036	1.092	1.109
3	1.637	1.062	1.271	1.172	1.293	1.062	1.151	1.162	1.370	1.051	1.137	1.125
6	1.736	1.044	1.269	1.190	1.328	1.061	1.167	1.161	1.563	1.066	1.161	1.148
9	1.515	0.979	1.161	1.213	1.300	1.056	1.149	1.161	1.485	1.054	1.154	1.144
12	0.900	0.801	0.879	1.208	1.339	1.044	1.147	1.147	1.460	1.032	1.129	1.125
15	0.803	0.714	0.789	1.185	1.313	0.999	1.103	1.104	1.273	0.979	1.051	1.080
18	0.795	0.696	0.767	***	0.921	0.813	0.867	***	0.904	0.820	0.855	***

	25 Feet				19 Feet				12.5 Feet			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	1.204	0.973	1.044	1.095	1.210	1.041	1.084	1.091	1.149	0.976	1.014	1.074
3	1.271	1.061	1.105	1.110	1.292	1.038	1.097	1.102	1.334	1.038	1.075	1.092
6	1.440	1.073	1.154	1.148	1.345	1.046	1.126	1.121	1.503	1.057	1.134	1.112
9	1.454	1.065	1.161	1.137	1.332	1.026	1.104	1.125	1.446	1.024	1.111	1.113
12	1.484	1.032	1.125	1.130	1.313	0.994	1.086	1.109	1.372	0.984	1.068	1.095
15	1.453	0.983	1.081	1.090	1.236	0.963	1.043	1.086	1.297	0.945	1.026	1.055
18	0.953	0.847	0.886	***	0.891	0.802	0.839	***	0.772	0.706	0.728	***

	7 Feet				Quoin (Land Wall)			
DEPTH	ON	OFF	IOP[1]	IOP[2]	ON	OFF	IOP[1]	IOP[2]
Sill	0.796	0.757	0.763	0.900	0.884	0.803	0.821	0.793
3	1.060	0.932	0.945	0.995	1.153	0.958	0.860	0.832
6	1.093	0.945	0.994	1.020	1.250	0.963	1.036	0.850
9	1.123	0.936	0.985	1.020	1.400	0.937	1.012	0.895
12	1.117	0.902	0.961	1.027	1.206	0.879	0.939	0.849
15	1.018	0.847	0.898	1.036	0.855	0.716	0.754	0.717
18	0.752	0.676	0.698	***	0.530	0.517	0.522	***

PIKE ISLAND RECTIFIER
ISLAND (RIVER) WALL - USG
6/12/91

Manufacturer:	Goodall
Model:	TIAYCD 24-40/30/16/GGNPSZ
Type:	0031451 - 4 Circuits
Serial Number:	86A1084
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2	CIRCUIT #3	CIRCUIT #4
10.79 Volts (25)	7.43 Volts (17)	9.04 Volts (17)	6.10 Volts
7.00 Amperes (13)	3.92 Amperes (3)	2.76 Amperes (2)	0.69 Amperes
Shunt Size 50mV/50A	Shunt Size 50mV/40A	Shunt Size 50mV/20A	Shunt Size 50mV/8A
Shunt mV = 7.0	Shunt mV = 4.9	Shunt mV = 6.9	Shunt mV = 4.3
Watts = 76	Watts = 29	Watts = 25	Watts = 4.2

Total Secondary Watts for this rectifier = 134

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV).

Quoin & Miter Anode Strings		Back Center Anode Strings		Stub Anode Strings		Skin Anode Disks	
EAR No.	Amperes	EAR No.	Amperes	EAR No.	Amperes	LSA No.	Amperes
E2	0.85	A2	0.57	A1	0.13	1	0.05
F2	0.84	B2	0.51	B1	0.17	2	0.05
G2	0.90	C2	0.46	C1	0.16	3	0.04
H2	0.93	D2	0.39	D1	0.16	4	0.05
I2	0.89	M2	0.52	E1	0.14	5	0.04
J2	0.80	N2	0.52	F1	0.16	6	0.04
K2	0.91	O2	0.48	G1	0.16	7	0.04
L2	0.82	P2	0.47	H1	0.10	8	0.05
TOTAL	6.94	**TOTAL**	3.92	I1	0.14	9	0.04
				J1	0.18	10	0.04
				K1	0.15	11	0.04
				L1	0.27	12	0.04
				M1	0.15	13	0.04
				N1	0.15	14	0.04
				O1	0.14	15	0.04
				P1	0.20	**TOTAL**	0.64
				TOTAL	2.56		

PIKE ISLAND RECTIFIER
LAND WALL - USG
6/12/91

Manufacturer:	Goodall
Model:	CSAWSD - 24/30 HNPSE - 24/16
Type:	0031449 - 2 Circuits
Serial Number:	86C1951
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
16.54 Volts (30)	5.13 Volts
18.16 Amperes (31)	0.48 Amperes
Shunt Size 50mV/40A	Shunt Size 50mV/20A
Shunt mV = 22.7	Shunt mV = 1.2
300 Watts	2.5 Watt

Total Secondary Watts = 303

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV)

Quoin, Miter & Back Center
Anode Strings

EAR No.	Amperes
A	2.4
B	2.1
C	2.2
D	2.3
E	2.1
F	2.1
G	2.3
H	2.2
TOTAL	17.7

Skin
Anode Disk

LSA No.	Amperes
1	0.03
2	0.03
3	0.03
4	0.03
5	0.03
6	0.03
7	0.03
8	0.03
9	0.03
10	0.03
11	0.03
12	0.03
13	0.03
14	0.02
15	0.02
TOTAL	0.43

PIKE ISLAND RECTIFIER
ISLAND (RIVER) WALL- DSG
6/12/91

Manufacturer:	Goodall
Model:	CSAWSD - 24/30 HNPSE - 24/16
Type:	0031449 - 2 Circuits
Serial Number:	86C1950
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
16.32 Volts (30)	4.73 Volts
12.32 Amperes (16 jumpy)	0.5 Amperes
Shunt Size 50mV/40A	Shunt Size 50mV/20A
Shunt mV = 15.4	Shunt mV = 1.3
201 Watts	2.5 Watt

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts ar 5A/50mV)

Quoin, Miter & Back Center
Anode Strings

EAR No.	Amperes
A	2.7
B	1.3
C	1.2
D	1.1
E	1.1
F	1.2
G	1.1
H	2.8
TOTAL	12.5

Note: Strings "A" & "H" above are located on the Upstream Side (USS) of the gate (Quoin & Miter) and are more than twice as long as the other strings. This makes the their resistance 1/2 the others and doubles the current. The chamber pool was full.

Skin
Anode Disk

LSA No.	Amperes
1	0.02
2	0.02
3	0.02
4	0.02
5	0.02
6	0.02
7	0.02
8	0.02
9	0.02
10	0.02
11	0.02
12	0.02
13	0.02
14	0.02
15	0.02
16	0.02
17	0.02
18	0.01
19	0.02
20	0.02
21	0.02
22	0.02
23	0.02
TOTAL	0.45

PIKE ISLAND RECTIFIER
LAND WALL- DSG
6/12/91

Manufacturer: Goodall

Model: CSAWSD - 24/30
HNPSE - 24/16

Type: 0031449 - 2 Circuits

Serial Number: 86C1949

Primary: 480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C

Output: 24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
17.2 Volts (30)	4.98 Volts
12.08 Amperes (18)	0.64 Amperes
Shunt Size 50mV/40A	Shunt Size 50mV/20A
Shunt mV = 15.1	Shunt mV = 1.6
208 Watts	3.2 Watt

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV)

Quoin, Miter & Back Center
Anode Strings

EAR No.	Amperes
A	2.6
B	1.4
C	1.3
D	1.1
E	1.1
F	1.1
G	1.2
H	2.7
TOTAL	12.5

Note: Strings "A" & "H" above are located on the Upstream Side (USS) of the gate (Quoin & Miter) and are more than twice as long as the other strings. This makes the their resistance 1/2 the others and doubles the current. The chamber pool was full.

Skin
Anode Disk

LSA No.	Amperes
1	0.03
2	0.02
3	0.03
4	0.03
5	0.02
6	0.02
7	0.03
8	0.03
9	0.03
10	0.03
11	0.03
12	0.03
13	0.03
14	0.03
15	0.03
16	0.02
17	0.02
18	0.02
19	0.02
20	0.02
21	0.03
22	0.03
23	0.03
TOTAL	0.61

PIKE ISLAND (RIVER) WALL - USG
2/15/91

Manufacturer:	Goodall
Model:	TIAYCD 24-40/30/16/GGNPSZ
Type:	0031451 - 4 Circuits
Serial Number:	86A1084
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2	CIRCUIT #3	CIRCUIT #4
25.60 Volts	17.80 Volts	17.70 Volts	9.70 Volts
4.09 Amperes	3.99 Amperes	2.35 Amperes	0.50 Amperes
Shunt Size 50mV/50A	Shunt Size 50mV/40A	Shunt Size 50mV/20A	Shunt Size 50mV/8A
Shunt mV = 4.09	Shunt mV = 4.99	Shunt mV = 5.89	Shunt mV = 3.14
105 Watts	71 Watts	42 Watts	5 Watts

Total Secondary Watts = 223

TERMINAL BOX DATA

Anode String		Anode String		Anode String		Anode Disk	
EAR No.	Amperes	EAR No.	Amperes	EAR No.	Amperes	LSA No.	Amperes
E2	0.788	A2	0.674	A1	0.123	1	0.034
F2	0.756	B2	0.612	B1	0.178	2	0.033
G2	0.833	C2	0.450	C1	0.134	3	0.032
H2	0.829	D2	0.422	D1	0.127	4	0.033
I2	0.747	M2	0.729	E1	0.125	5	0.033
J2	0.750	N2	0.650	F1	0.170	6	0.033
K2	0.802	O2	0.466	G1	0.136	7	0.033
L2	0.742	P2	0.493	H1	0.209	8	0.033
				I1	0.139	9	0.034
				J1	0.192	10	0.031
				K1	0.140	11	0.034
				L1	0.296	12	0.034
				M1	0.000	13	0.032
				N1	0.000	14	0.031
				O1	0.086	15	0.029
				P1	0.308		

PIKE ISLAND RECTIFIER
LAND WALL - USG
2/15/91

Manufacturer:	Goodall
Model:	CSAWSD - 24/30 HNPSE - 24/16
Type:	0031449 - Circuits
Serial Number:	86C1951
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

<u>CIRCUIT #1</u>

29.50 Volts
10.24 Amperes
Shunt Size 50mV/40A
Shunt mV = 12.80
302 Watts

<u>CIRCUIT #2</u>

5.12 Volts
0.18 Amperes
Shunt Size 50mV/20A
Shunt mV = .46
1 Watt

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV)

Quoin, Miter & Back Center
<u>Anode Strings</u>

EAR No.	Amperes
A	1.876
B	1.487
C	1.611
D	1.555
E	1.460
F	1.488
G	1.568
H	1.592

Skin
<u>Anode Disk</u>

LSA No.	Amperes
1	0.010
2	0.010
3	0.009
4	0.010
5	0.010
6	0.009
7	0.009
8	0.010
9	0.009
10	0.009
11	0.009
12	0.009
13	0.009
14	0.009
15	0.009

PIKE ISLAND RECTIFIER
ISLAND (RIVER) WALL- DSG
2/15/91

Manufacturer:	Goodall
Model:	CSAWSD - 24/30 HNPSE - 24/16
Type:	0031449 - 2 Circuits
Serial Number:	86C1950
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1	CIRCUIT #2
30.29 Volts	5.33 Volts
9.50 Amperes	0.23 Amperes
Shunt Size 50mV/40A	Shunt Size 50mV/20A
Shunt mV = 11.88	Shunt mV = .57
288 Watts	1 Watt

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV)

Quoin, Miter & Back Center
Anode Strings

EAR No.	Amperes
A	2.112
B	1.064
C	0.964
D	0.781
E	0.781
F	0.875
G	0.906
H	2.084

Skin
Anode Disk

LSA No.	Amperes
1	0.008e
2	0.010
3	0.010
4	0.011
5	0.010
6	0.009
7	0.009
8	0.009
9	0.010
10	0.009
11	0.009
12	0.009
13	0.009
14	0.009
15	0.010
16	0.009
17	0.009
18	0.005
19	0.007
20	0.005
21	0.009
22	0.009
23	0.008

PIKE ISLAND RECTIFIER
LAND WALL- DSG
2/15/91

Manufacturer:	Goodall
Model:	CSAWSD - 24/30 HNPSE - 24/16
Type:	0031449 - 2 Circuits
Serial Number:	86C1949
Primary:	480 VAC, 2.39/1.27 Amperes, Single Phase, 60 Hz, 45°C
Output:	24/24 Volts, 3/16 Amperes

OPERATING DATA

CIRCUIT #1

29.69 Volts
9.12 Amperes
Shunt Size 50mV/40A
Shunt mV = 11.39
271 Watts

CIRCUIT #2

5.22 Volts
0.23 Amperes
Shunt Size 50mV/20A
Shunt mV = .57
1 Watt

TERMINAL BOX DATA

(The terminal box shunt readings have been converted to amperes below. Shunts are 5A/50mV)

Quoin, Miter & Back Center
Anode Strings

EAR No.	Amperes
A	1.735
B	1.079
C	0.953
D	0.750
E	0.728
F	0.944
G	0.972
H	1.847

Skin
Anode Disk

LSA No.	Amperes
1	0.012
2	0.011
3	0.013
4	0.015
5	0.011
6	0.012
7	0.013
8	0.013
9	0.013
10	0.012
11	0.011
12	0.012
13	0.012
14	0.012
15	0.012
16	0.011
17	0.012
18	0.010
19	0.010
20	0.010
21	0.012
22	0.011
23	0.010

APPENDIX E: Cordell Hull Dam Native Potentials (North Tainter Gate), 1988

CORDELL HULL LOCK AND DAM TAINER GATE
NORTH GATE NATIVE POTENTIAL DATA

4/20/88

(See drawing for South Gate in Appendix F for Data Locations)

	A	C	E	G	I	K	M
Surface	0.402	0.362	0.279	0.262	0.278	0.346	0.381
3	0.466	0.342	0.276	0.260	0.273	0.342	0.511
6	0.481	0.353	0.270	0.258	0.266	0.332	0.526
9	0.462	0.333	0.262	0.255	0.259	0.315	0.527
12	0.460	0.301	0.255	0.251	0.251	0.290	0.515
15	0.300	0.259	0.249	0.249	0.244	0.255	0.393
18	0.265	0.232	0.244	0.247	0.238	0.228	0.261
21	0.244	0.223	0.242	0.249	0.237	0.216	0.195
24	0.254	0.227	0.243	0.252	0.269	0.218	0.202
27	0.258	0.239	0.247	0.255	0.244	0.228	0.229
30	0.271	0.253	0.253	0.257	0.249	0.241	0.247
33	0.283	0.268	0.258	0.259	0.254	0.254	0.261
36	0.289	0.275	0.261	0.259	0.256	0.261	0.269
37	0.291	0.275	0.261	0.259	0.257	0.261	0.271

DETAILED EQUIPOTENTIAL BETWEEN ANODES #12 AND #13

According to the 1988 off potential data below, the polarization potential next to the LSA does not reach any value of concern from hydrogen production and paint damage. This remains true even if an additional 140 mV is added to the off potential readings as the instant off potential readings suggest should be done in some cases. See main body of data.

CENTER (#3) POSITION

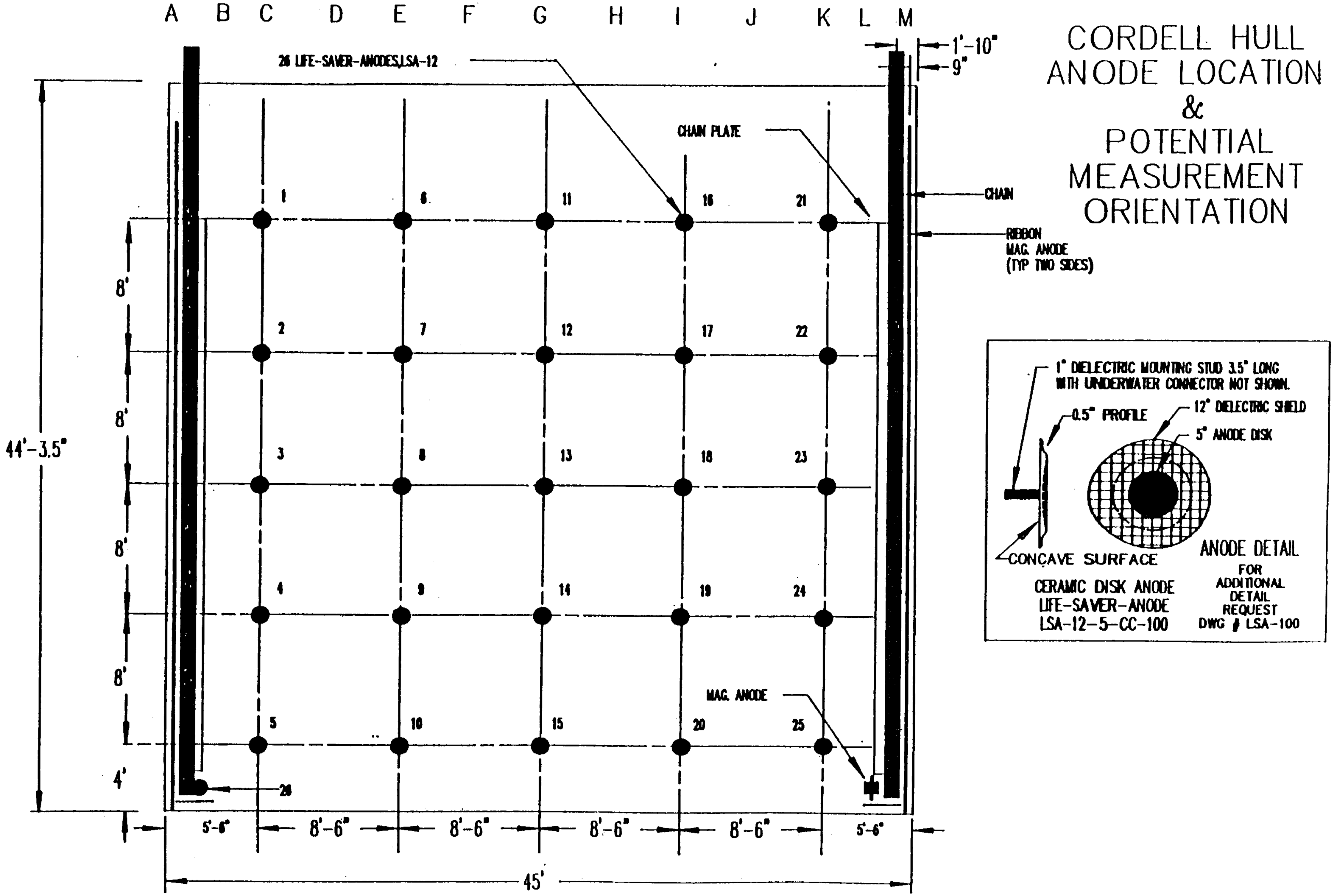
EQUIPOTENTIAL AT CENTER OF GATE

DISTANCE*	ON POTENTIAL	OFF POTENTIAL
At Anode Center #13	18.20	0.88
2 in.	16.90	0.89
4 in.	10.54	0.76
6 in.	8.08	0.73
8 in.	7.03	0.72
10 in.	6.51	0.71
12 in.	6.12	0.72
2 ft.	4.98	0.70
3 ft.	4.61	0.70
4 ft.	4.48	0.70
5 ft.	4.51	0.69
6 ft.	4.91	0.69
7 ft.	6.71	0.69
7 ft. 2 in.	7.84	0.70
7 ft. 4 in.	9.59	0.70
At Anode Center #12	12.48	0.71

* Distance away from center of Anode #13 moving up to Anode #12

APPENDIX F: CERANODE Survey Data for Cordell Hull Dam, 1989

CORDELL HULL ANODE LOCATION & POTENTIAL MEASUREMENT ORIENTATION



CORDELL HULL READINGS
(8/25/89)

A

	ON	OFF	IOP	DECAY	DELTA
Bottom	1.313	0.853	0.917	0.681	0.236
3	1.310	0.814	0.884	0.705	0.179
6	1.302	0.801	0.883	0.662	0.221
9	1.277	0.839	0.916	0.684	0.232
12	1.076	0.809	0.867	0.684	0.183
15	0.966	0.817	0.872	0.688	0.184
18	0.944	0.798	0.857	0.746	0.111
21	0.979	0.858	0.907	0.785	0.122
24	0.986	0.848	0.926	0.782	0.144
27	1.184	1.000	1.109	0.825	0.284
30	1.183	0.993	1.108	0.803	0.305
33	1.351	1.079	1.229	0.802	0.427
36	1.330	1.052	1.208	0.746	0.462
39	1.288	1.027	1.178	0.672	0.506

D

	ON	OFF	IOP	DECAY	DELTA
Bottom	2.089	0.800	0.899	0.665	0.234
3	2.170	0.765	0.869	0.634	0.235
6	2.272	0.724	0.830	0.589	0.241
9	2.424	0.673	0.787	0.552	0.235
12	2.450	0.633	0.743	0.514	0.229
15	2.410	0.596	0.709	0.483	0.226
18	2.521	0.575	0.690	0.465	0.225
21	2.459	0.575	0.689	0.458	0.231
24	2.512	0.582	0.709	0.462	0.247
27	2.662	0.611	0.743	0.474	0.269
30	2.577	0.638	0.779	0.491	0.288
33	2.735	0.666	0.818	0.508	0.310
36	2.742	0.692	0.846	0.521	0.325
39	2.578	0.702	0.857	0.521	0.336

CORDELL HULL READINGS
(8/25/89)

F

	ON	OFF	IOP	DECAY	DELTA
Bottom	2.300	0.832	0.940	0.684	0.256
3	2.336	0.786	0.900	0.659	0.241
6	2.504	0.752	0.871	0.621	0.250
9	2.771	0.718	0.849	0.584	0.265
12	2.863	0.688	0.824	0.550	0.274
15	2.838	0.662	0.807	0.527	0.280
18	3.096	0.630	0.779	0.507	0.272
21	3.000	0.619	0.758	0.495	0.263
24	3.055	0.618	0.758	0.488	0.270
27	3.234	0.623	0.770	0.489	0.281
30	3.111	0.627	0.781	0.492	0.289
33	3.244	0.639	0.801	0.496	0.305
36	3.238	0.650	0.817	0.500	0.317
39	3.069	0.648	0.819	0.501	0.318

H

	ON	OFF	IOP	DECAY	DELTA
Bottom	2.191	0.786	0.911	0.667	0.244
3	2.272	0.767	0.891	0.646	0.245
6	2.458	0.737	0.866	0.615	0.251
9	2.726	0.704	0.838	0.589	0.249
12	2.846	0.673	0.815	0.560	0.255
15	2.894	0.652	0.792	0.535	0.257
18	3.069	0.633	0.780	0.516	0.264
21	3.036	0.624	0.770	0.505	0.265
24	3.080	0.624	0.771	0.499	0.272
27	3.182	0.628	0.777	0.498	0.279
30	3.100	0.634	0.789	0.498	0.291
33	3.233	0.644	0.811	0.502	0.309
36	3.211	0.647	0.821	0.505	0.316
39	3.065	0.654	0.822	0.506	0.316

CORDELL HULL READINGS
(8/25/89)

J

	ON	OFF	IOP	DECAY	DELTA
Bottom	2.036	0.805	0.913	0.690	0.223
3	2.154	0.743	0.859	0.639	0.220
6	2.248	0.707	0.823	0.596	0.227
9	2.424	0.672	0.791	0.555	0.236
12	2.450	0.639	0.760	0.524	0.236
15	2.476	0.622	0.738	0.499	0.239
18	2.635	0.608	0.743	0.484	0.259
21	2.536	0.609	0.743	0.478	0.265
24	2.565	0.612	0.747	0.482	0.265
27	2.681	0.630	0.768	0.493	0.275
30	2.594	0.655	0.798	0.509	0.289
33	2.689	0.691	0.839	0.528	0.311
36	2.656	0.710	0.868	0.544	0.324
39	2.468	0.723	0.878	0.551	0.327

L

	ON	OFF	IOP	DECAY	DELTA
Bottom	1.690	0.785	0.872	0.806	0.066
3	1.568	0.750	0.831	0.722	0.109
6	1.569	0.739	0.817	0.719	0.098
9	1.660	0.721	0.801	0.719	0.082
12	1.617	0.719	0.793	0.712	0.081
15	1.520	0.712	0.784	0.720	0.064
18	1.728	0.687	0.775	0.716	0.059
21	1.419	0.740	0.862	0.625	0.237
24	1.372	0.792	0.952	0.869	0.083
27	1.752	0.797	0.945	0.872	0.073
30	1.680	0.820	0.964	0.863	0.101
33	1.680	0.907	1.061	0.839	0.222
36	1.672	0.929	1.098	0.793	0.305
39	1.599	0.894	1.042	0.717	0.325

CORDELL HULL READINGS
(8/25/89)

	ON	OFF	M IOP	DECAY	DELTA
Bottom	1.273	0.888	0.937	0.701	0.236
3	1.312	0.832	0.899	0.673	0.226
6	1.301	0.840	0.909	0.652	0.257
9	1.243	0.844	0.906	0.636	0.270
12	0.993	0.820	0.877	0.607	0.270
15	1.027	0.872	0.955	0.583	0.372
18	1.032	0.859	0.950	0.542	0.408
21	0.901	0.796	0.850	0.541	0.309
24	1.038	0.907	0.986	0.572	0.414
27	1.115	0.971	1.052	0.586	0.466
30	1.137	0.982	1.073	0.619	0.454
33	1.297	1.072	1.189	0.647	0.542
36	1.308	0.988	1.129	0.660	0.469
39	1.351	0.920	1.049	0.659	0.390

CORDELL HULL

RECTIFIER READINGS

CIRCUIT #2	CIRCUIT #1	CIRCUIT #3
18.74 Volts	20.42 Volts	20.77 Volts
0.36 Amperes	0.64 Amperes	0.94 Amperes
7.7 Watts	13.1 Watts	15.9 Watts

JUNCTION BOX READINGS
(8/25/89)

CIRCUIT #2		CIRCUIT #1		CIRCUIT #3	
ANODE NO.	CURRENT	ANODE NO.	CURRENT	ANODE NO.	CURRENT
5	0.072	1	0.080	6	0.080
10	0.072	2	0.074	7	0.073
15	0.065	3	0.072	8	0.072
20	0.069	4	0.075	9	0.074
25	0.068	21	0.078	11	0.078
		22	0.076	12	0.074
		23	0.000	13	0.073
		24	0.082	14	0.074
		26	0.078	16	0.078
				17	0.074
				18	0.073
				19	0.074

Total Power Before With % Efficient Rectifier = 7.7 + 13.1 + 15.9
Divided by 0.80 = 46 Watts

CORDELL HULL

DEPOLARIZATION DECAY CHART
(8/25/89)

TIME	POTENTIAL
IOP *	0.778
OFF **	0.633
0:00:08	0.600
0:00:25	0.585
0:00:30	0.582
0:00:45	0.577
0:00:60	0.574
0:01:30	0.569
0:02:00	0.565
0:02:30	0.563
0:03:00	0.561
0:04:00	0.557
0:05:00	0.555
0:06:00	0.553
0:07:00	0.551
0:08:00	0.550
0:09:00	0.549
0:10:00	0.549
0:17:00	0.541
0:30:00	0.534
4:57:00	0.530
5:12:00	0.524
5:52:00	0.517
6:12:00	0.516

* IOP = Instant Off Potential as measured with Xetron and verfied with Leader LCD-100 Scope

** OFF = Off Potential measured with 2nd Fluke Model 75 DVM Update

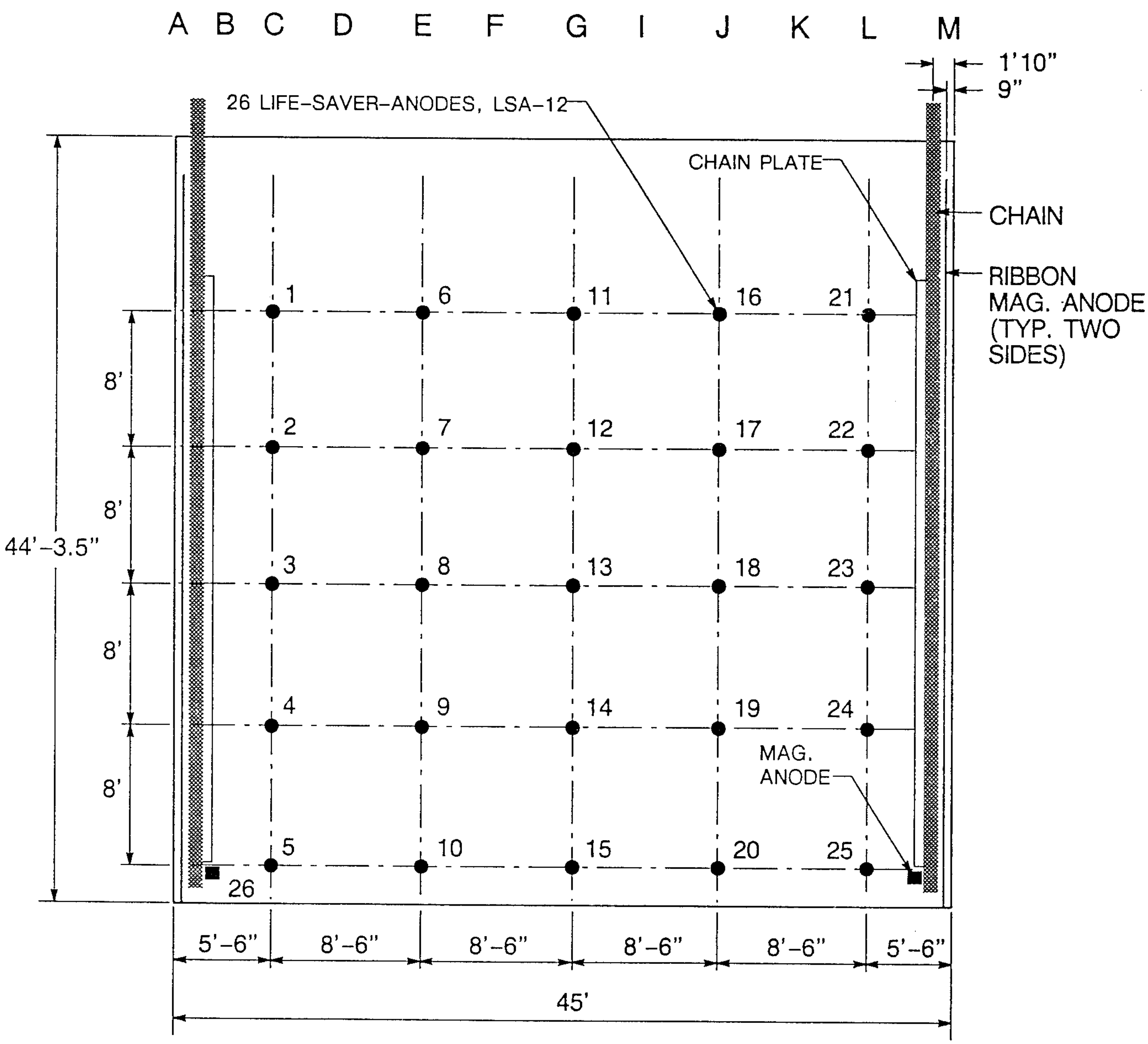
APPENDIX G: Survey Data for Cordell Hull Dam (South Tainter Gate), 1991

CORDELL HULL TAINTER DAM GATE

ANODE LOCATION

&

POTENTIAL MEASUREMENT ORIENTATION



CORDELL HULL READINGS
(3/04/91)

	A				D			
	ON DVM	OFF* DVM	IOP CPA	IOP SP-1	ON DVM	OFF DVM	IOP CPA	mV Shift
Sill		Gate was open 3 feet because of flooding conditions						
Gate Seal	1.093	1.096	1.045	0.832	3.580	0.622	0.719	97
3	1.250	1.011	1.148	0.853	1.636	0.591	0.695	104
6	1.074	0.859	0.930	0.817	2.662	0.559	0.671	112
9	1.005	0.814	0.850	0.799	3.000	0.526	0.664	138
12	1.053	0.813	0.949	0.785	2.432	0.506	0.661	155
15	1.195	1.032	1.108	0.809	4.340	0.493	0.658	165
18	1.231	1.060	1.129	0.826	2.671	0.503	0.659	156
21	1.156	0.951	1.020	0.830	2.670	0.548	0.720	172
24	1.129	0.986	1.045	0.832	3.460	0.575	0.803	228
27	1.145	0.949	1.042	0.834	3.520	0.605	0.857	252
30	1.110	0.925	1.020	0.822	4.070	0.619	0.912	293
33	1.200	0.863	0.960	0.844	4.360	0.629	0.930	301

	F				H			
	ON DVM	OFF DVM	IOP CPA	IOP SP-1	ON DVM	OFF DVM	IOP CPA	mV Shift
Sill		Gate was open 3 feet because of flooding condition						
Gate Seal	1.850	0.684	0.836	152	4.050	0.723	0.901	178
3	2.297	0.683	0.894	211	2.611	0.704	0.898	194
6	2.940	0.717	0.950	233	3.087	0.604	0.903	299
9	3.750	0.681	0.983	302	2.677	0.573	0.758	185
12	3.150	0.680	0.954	274	2.800	0.575	0.744	169
15	3.580	0.661	0.974	313	3.780	0.635	0.999	364
18	3.920	0.601	0.924	323	3.600	0.612	0.924	312
21	4.220	0.595	0.942	347	3.890	0.597	0.924	327
24	1.766	0.603	1.141	538	5.220	0.601	1.039	438
27	4.720	0.595	0.974	379	4.650	0.599	0.970	371
30	5.140	0.605	0.991	386	4.920	0.614	0.986	372
33	5.060	0.604	0.962	358	5.280	0.620	1.007	381

*Ribbon Magnesium Anodes present near the edges

CORDELL HULL READINGS
(3/04/91)

	J				L			
	ON DVM	OFF DVM	IOP CPA	IOP SP-1	ON DVM	OFF DVM	IOP CPA	mV Shift*
Sill		Gate was	open 3	feet	because of	flooding	condition	
Gate Seal	2.100	0.720	0.871	151	2.128	0.744	0.885	141
3	2.268	0.650	0.839	189	2.170	0.672	0.852	180
6	2.700	0.606	0.788	182	2.525	0.636	0.824	152
9	1.400	0.617	0.800	183	2.787	0.617	0.805	188
12	2.200	0.578	0.774	187	2.525	0.584	0.775	191
15	2.800	0.579	0.809	230	3.040	0.754	0.833	79
18	2.840	0.588	0.835	247	2.870	0.676	0.866	190
21	2.945	0.619	0.870	251	2.852	0.630	0.863	233
24	3.238	0.661	0.943	282	4.360	0.636	0.943	307
27	3.460	0.641	0.958	317	3.430	0.663	0.948	285
30	4.260	0.661	0.985	324	3.850	0.705	1.004	299
33	4.230	0.681	1.006	325	5.901	0.753	1.098	345

	M			
	ON DVM	OFF * DVM	IOP CPA	IOP SP-1
Sill		Gate was	open 3	feet because of flooding condition
Gate Seal	0.680	0.594	0.711	0.750
3	0.824	0.914	0.800	0.680
6	0.775	***	***	0.640
9	0.830	0.706	0.750	0.633
12	0.960	0.772	0.850	0.693
15	0.898	0.773	0.785	0.674
18	0.950	0.761	0.844	0.700
21	0.955	0.863	0.912	0.690
24	0.968	0.869	0.927	0.725
27	1.043	0.962	0.990	0.770
30	1.140	0.904	0.989	0.786
33	1.196	0.963	0.957	0.800

CORDELL HULL

RECTIFIER READINGS

Manufacturer:	Universal Rectifier
Model:	ASP-CC
Type:	Constant Current Saturable Reactor - 3 Circuits
Serial Number:	860936
Primary:	120 VAC, 1 Ph, 60 Hz
Output:	24/24/24 Volts, 2/2/2 Amperes

Features: Analog Ampere and Voltage Meters, Meter Switch, UR Company Switches, Multiturn Current Adjustment/Circuit

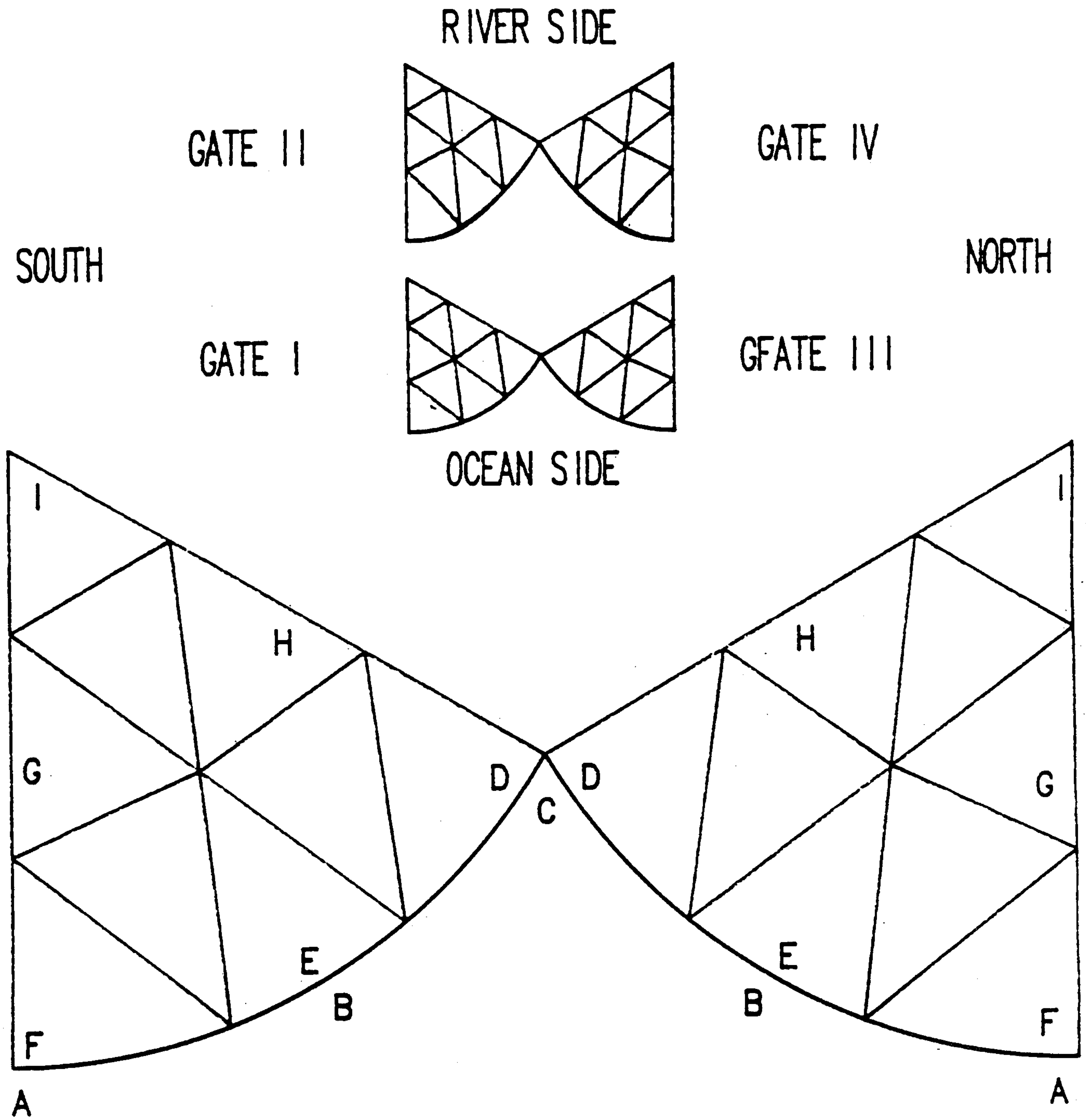
CIRCUIT #2	CIRCUIT #1	CIRCUIT #3
23.25 Volts	23.50 Volts	24.00 Volts
0.33 Amperes	0.50 Amperes	0.80 Amperes
7.56 Watts	11.75 Watts	19.20 Watts

JUNCTION BOX READINGS
(3/04/91)

CIRCUIT #2		CIRCUIT #1		CIRCUIT #3	
ANODE NO.	CURRENT	ANODE NO.	CURRENT	ANODE NO.	CURRENT
5	0.054	1	0.054	6	0.0675
10	0.063	2	0.050	7	0.060
15	0.056	3	0.050	8	0.058
20	0.063	4	0.050	9	0.060
25	0.062	21	0.064	11	0.064
		22	0.063	12	0.061
		23	***	13	0.061
		24	0.063	14	0.062
		26	0.061	16	0.065
				17	0.063
				18	0.064
				19	0.063

Total Power Rectifier = 7.6 + 11.8 + 19.2 = 38.6 Watts

APPENDIX H: CERANODE Survey Data for Cape Canaveral, 1989 Data



CANAVERAL LOCKS

POTENTIAL SURVEY

MEASUREMENT LOCATIONS

CAPE CANAVERAL READINGS
(8/29/89)

GATE NO. 1

	A				B				C			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.908	0.891	0.731	0.160	0.922	0.887	0.737	0.150	0.972	0.956	0.724	0.232
Middle	0.941	0.904	0.741	0.163	0.944	0.890	0.743	0.147	1.010	0.963	0.731	0.232
Top	0.939	0.903	0.740	0.163	0.946	0.891	0.743	0.148	1.010	0.968	0.734	0.234

	D				E				F			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.922	0.915	0.743	0.172	0.924	0.909	0.755	0.154	0.910	0.898	0.735	0.163
Middle	0.927	0.919	0.743	0.176	0.932	0.919	0.758	0.161	0.917	0.904	0.736	0.168
Top	0.931	0.923	0.743	0.180	0.932	0.921	0.759	0.162	0.916	0.909	0.736	0.173

	G				H				I			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.916	0.903	0.739	0.164	0.911	0.903	0.744	0.159	0.902	0.897	0.745	0.152
Middle	0.918	0.903	0.739	0.164	0.914	0.905	0.743	0.162	0.904	0.896	0.744	0.152
Top	0.917	0.904	0.739	0.165	0.912	0.905	0.741	0.164	0.902	0.896	0.744	0.152

CÀPE CANAVERAL READINGS
(8/29/89)

GATE NO. 3

	A				B				C			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.941	0.921	0.741	0.180	0.961	0.942	0.734	0.208	0.972	0.956	0.724	0.232
Middle	0.955	0.927	0.746	0.181	0.980	0.925	0.727	0.184	1.010	0.963	0.731	0.232
Top	0.950	0.922	0.747	0.175	0.976	0.922	0.728	0.180	1.010	0.968	0.734	0.234

	D				E				F			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.927	0.921	0.748	0.173	0.947	0.938	0.750	0.188	0.936	0.927	0.751	0.176
Middle	0.933	0.927	0.748	0.179	0.952	0.939	0.750	0.189	0.941	0.931	0.752	0.179
Top	0.933	0.927	0.748	0.179	0.952	0.939	0.750	0.189	0.941	0.933	0.752	0.181

	G				H				I			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.939	0.925	0.753	0.172	0.926	0.920	0.755	0.165	0.912	0.907	0.755	0.152
Middle	0.937	0.924	0.753	0.171	0.927	0.921	0.755	0.166	0.915	0.907	0.754	0.153
Top	0.937	0.925	0.753	0.172	0.956	0.921	0.754	0.167	0.915	0.909	0.754	0.155

CAPE CANAVERAL READINGS
(8/29/89)

GATE NO. 2

	A				B				C			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.888	0.871	0.763	0.108	0.902	0.881	0.768	0.113	0.934	0.925	0.759	0.166
Middle	0.897	0.880	0.765	0.115	0.916	0.878	0.768	0.110	0.951	0.927	0.764	0.163
Top	0.893	0.877	0.764	0.113	0.920	0.878	0.768	0.110	0.966	0.933	0.761	0.172

	D				E				F			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.884	0.880	0.766	0.114	0.888	0.881	0.759	0.122	0.891	0.881	0.760	0.121
Middle	0.893	0.886	0.766	0.120	0.895	0.886	0.762	0.124	0.895	0.886	0.761	0.125
Top	0.889	0.884	0.766	0.118	0.896	0.889	0.762	0.127	0.893	0.886	0.761	0.125

	G				H				I			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.890	0.880	0.765	0.115	0.883	0.874	0.767	0.107	0.877	0.871	0.766	0.105
Middle	0.891	0.880	0.765	0.115	0.885	0.878	0.766	0.112	0.877	0.870	0.765	0.105
Top	0.891	0.880	0.765	0.115	0.883	0.878	0.765	0.113	0.876	0.869	0.765	0.104

CAPE CANAVERAL READINGS
(8/29/89)

GATE NO. 4

	A				B				C			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.876	0.861	0.760	0.101	0.897	0.886	0.767	0.119	0.934	0.925	0.759	0.166
Middle	0.892	0.869	0.768	0.101	0.912	0.873	0.770	0.103	0.951	0.927	0.764	0.163
Top	0.895	0.879	0.767	0.112	0.917	0.872	0.770	0.102	0.946	0.933	0.761	0.172

	D				E				F			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.883	0.880	0.770	0.110	0.895	0.891	0.768	0.123	0.892	0.885	0.769	0.116
Middle	0.888	0.884	0.769	0.115	0.901	0.892	0.769	0.123	0.897	0.890	0.768	0.122
Top	0.887	0.884	0.769	0.115	0.900	0.892	0.769	0.123	0.896	0.888	0.768	0.120

	G				H				I			
DEPTH	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT	ON	IOP	DECAY	SHIFT
Bottom	0.896	0.882	0.769	0.113	0.882	0.878	0.771	0.107	0.877	0.874	0.769	0.105
Middle	0.886	0.885	0.769	0.116	0.885	0.880	0.769	0.111	0.880	0.874	0.769	0.105
Top	0.896	0.885	0.769	0.116	0.882	0.880	0.768	0.112	0.880	0.874	0.768	0.106

CERANODE DATA ON CAPE CANAVERAL RECTIFIERS

CAPE CANAVERAL READINGS

GATE NO. 1

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860791

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (8/29/89)

Circuit No.	Volts	Shunt 1mV(10 mV = 1 Amperes)	Amperes Calculated	Amperes Meter
1	3.88	24.08	2.40	2.5
2	3.95	19.37	1.94	2.0
3	3.66	7.44	0.74	0.7
4	3.82	7.38	0.74	0.7
5	3.75	7.36	0.74	0.7
6	3.44	7.47	0.75	0.7
7	3.36	7.35	0.74	0.7
8	3.75	21.33	2.13	2.2

CAPE CANAVERAL RECTIFIERS

GATE NO. 3

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860789

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (8/29/89)

Circuit No.	Volts	Shunt 1mV(10 mV = 1 Amperes)	Amperes Calculated	Amperes Meter
1	4.04	25.22	2.52	2.5
2	3.94	20.51	2.05	2.0
3	3.66	7.58	0.76	0.7
4	3.62	7.66	0.77	0.7
5	3.56	7.68	0.77	0.7
6	3.47	7.57	0.76	0.7
7	3.42	7.54	0.75	0.7
8	4.02	22.19	2.22	2.2

CAPE CANAVERAL RECTIFIERS

GATE NO. 2

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860790

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (8/29/89)

Circuit No.	Volts	Shunt 1mV(10 mV = 1 Amperes)	Amperes Calculated	Amperes Meter
1	3.27	17.57	1.76	1.7
2	3.19	12.54	1.25	1.2
3	2.91	3.42	0.34	0.3
4	2.92	3.36	0.34	0.3
5	3.60	5.57	0.56	0.5
6	3.05	5.47	0.55	0.5
7	2.92	5.44	0.54	0.5
8	3.20	16.64	1.66	1.6

CAPE CANAVERAL RECTIFIERS

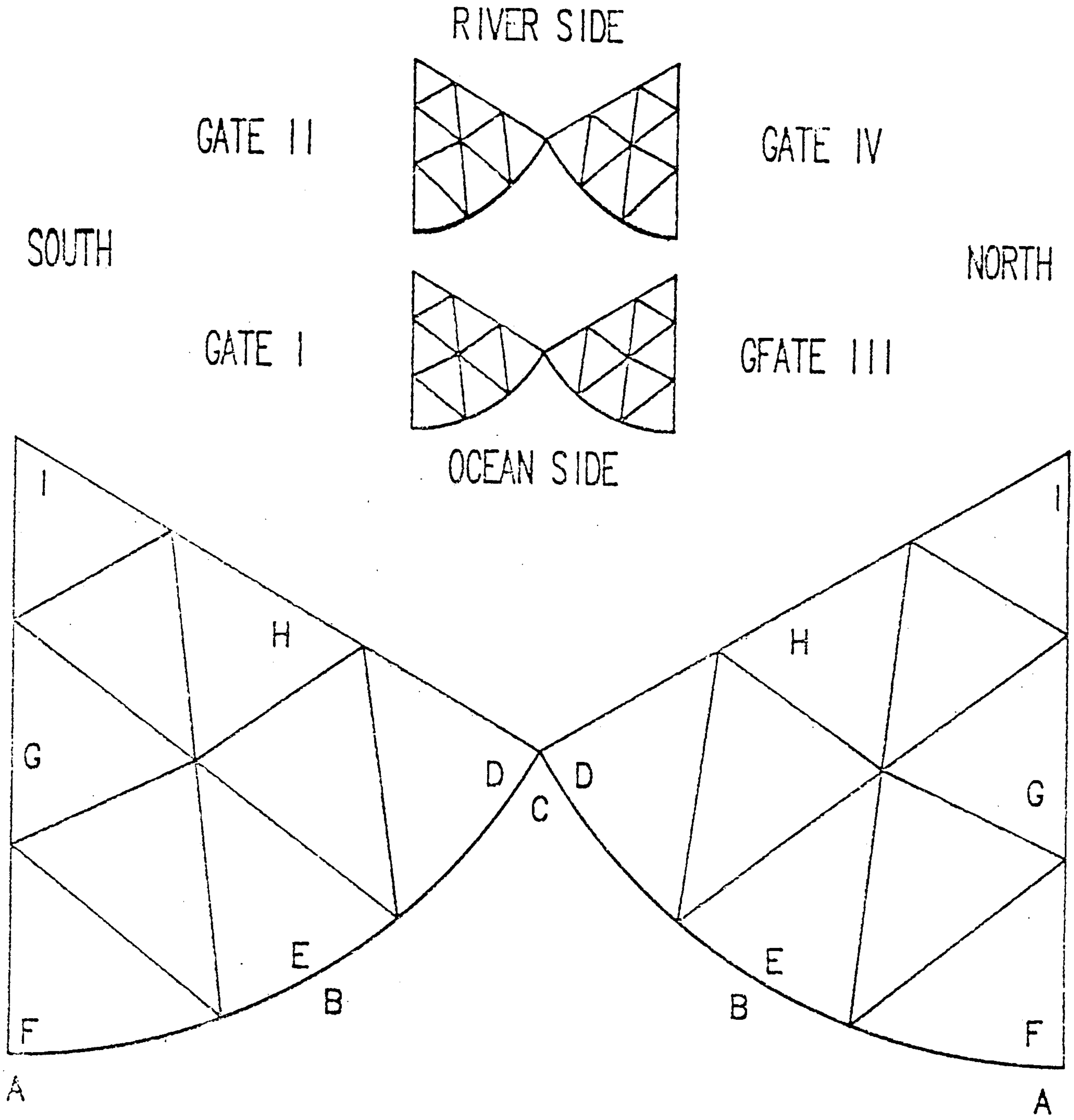
GATE NO. 4

Manufacturer:	Universal - 8 Circuits
Model:	ASP-CC
Type:	Constant Current
Serial Number:	860792
Primary:	120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C
Output:	24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (8/29/89)

Circuit No.	Volts	Shunt 1mV(10 mV = 1 Amperes)	Amperes Calculated	Amperes Meter
1	3.31	17.33	1.73	1.7
2	3.25	12.64	1.26	1.2
3	3.19	3.69	0.37	0.3
4	3.03	3.53	0.35	0.3
5	3.24	5.99	0.60	0.5
6	3.04	5.86	0.59	0.5
7	2.91	5.80	0.58	0.5
8	3.34	16.59	1.66	1.6

APPENDIX I: Potential Survey Data for Cape Canaveral, 1991 Data



CANAVERAL LOCKS

POTENTIAL SURVEY

MEASUREMENT LOCATIONS

CAPE CANAVERAL READINGS
(2/25/91)

GATE NO. 1

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.034	1.000	1.020	1.021	0.984	1.004	1.029	0.983	1.013
5′	1.045	1.011	1.027	1.033	0.995	1.010	1.038	0.984	1.019
10′	1.052	1.021	1.034	1.045	0.998	1.014	1.042	0.987	1.020
15′	1.058	1.023	1.038	1.045	1.006	1.021	1.052	0.994	1.027
Top	1.052	1.024	1.038	1.044	1.009	1.027	1.053	1.005	1.028

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.053	1.039	1.050	1.047	1.026	1.039	1.044	1.022	1.038
5′	1.053	1.039	1.050	1.046	1.026	1.042	1.053	1.028	1.044
10′	1.050	1.034	1.045	1.049	1.030	1.044	1.054	1.028	1.044
15′	1.048	1.042	1.047	1.054	1.033	1.050	1.059	1.033	1.050
Top	1.059	1.042	1.054	1.055	1.034	1.050	1.057	1.034	1.050

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.055	1.034	1.047	1.059	1.041	1.056	1.056	1.038	1.050
5′	1.055	1.033	1.048	1.058	1.041	1.056	1.057	1.037	1.050
10′	1.054	1.032	1.047	1.058	1.041	1.056	1.057	1.037	1.050
15′	1.055	1.033	1.048	1.058	1.041	1.054	1.057	1.036	1.050
Top	1.055	1.033	1.048	1.056	1.032	1.044	1.056	1.037	1.050

CAPE CANAVERAL READINGS
(2/25/91)

GATE NO. 3

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.040	1.015	1.032	1.020	0.995	1.013	1.029	0.989	1.022
5′	1.049	1.016	1.033	1.043	1.000	1.026	1.031	0.989	1.022
10′	1.044	1.018	1.034	1.039	1.004	1.028	1.035	0.992	1.026
15′	1.050	1.018	1.035	1.042	1.010	1.032	1.047	0.997	1.028
Top	1.044	1.019	1.034	1.043	1.011	1.032	1.049	0.999	1.031

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.057	1.046	1.056	1.072	1.058	1.067	1.073	1.054	1.068
5′	1.058	1.045	1.056	1.075	1.061	1.070	1.073	1.054	1.067
10′	1.060	1.048	1.057	1.077	1.063	1.072	1.076	1.055	1.068
15′	1.061	1.049	1.060	1.079	1.065	1.074	1.075	1.055	1.068
Top	1.062	1.050	1.060	1.078	1.063	1.075	1.073	1.054	1.068

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.068	1.055	1.067	1.067	1.050	1.062	1.064	1.051	1.042
5′	1.068	1.054	1.067	1.067	1.050	1.062	1.064	1.032	1.043
10′	1.068	1.054	1.066	1.067	1.049	1.062	1.064	1.050	1.062
15′	1.068	1.054	1.066	1.067	1.050	1.062	1.065	1.051	1.062
Top	1.066	1.054	1.065	1.067	1.049	1.062	1.063	1.050	1.060

CAPE CANAVERAL READINGS
(2/25/91)

GATE NO. 2

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.097	1.038	1.067	1.078	1.034	1.056	1.074	1.035	1.057
5′	1.102	1.040	1.069	1.079	1.035	1.056	1.076	1.036	1.057
10′	1.106	1.044	1.069	1.085	1.039	1.056	1.078	1.039	1.059
15′	1.117	1.045	1.070	1.094	1.043	1.057	1.085	1.041	1.061
Top	1.107	1.044	1.069	1.087	1.042	1.057	1.077	1.042	1.060

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.064	1.045	1.061	1.064	1.036	0.985	0.993	0.968	0.985
5′	1.066	1.046	1.062	1.062	1.036	0.984	0.995	0.970	0.985
10′	1.066	1.045	1.062	1.067	1.039	0.986	0.997	0.972	0.986
15′	1.067	1.046	1.062	1.068	1.041	1.060	1.067	1.041	1.057
Top	1.065	1.046	1.062	1.068	1.043	1.060	1.066	1.042	1.056

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.057	1.032	1.045	1.063	1.040	1.057	1.053	1.035	1.048
5′	1.057	1.032	1.045	1.063	1.043	1.057	1.052	1.033	1.047
10′	1.058	1.031	1.046	1.063	1.042	1.057	1.054	1.034	1.048
15′	1.058	1.031	1.047	1.063	1.043	1.057	1.054	1.033	1.048
Top	1.057	1.032	1.047	1.063	1.046	1.058	1.053	1.033	1.048

CAPE CANAVERAL READINGS
(2/25/91)

GATE NO. 4

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.066	1.031	1.050	1.073	1.031	1.047	1.092	1.026	1.057
5′	1.070	1.032	1.050	1.081	1.032	1.049	1.091	1.026	1.054
10′	1.071	1.035	1.050	1.080	1.033	1.050	1.094	1.031	1.056
15′	1.077	1.034	1.050	1.091	1.034	1.050	1.100	1.032	1.057
Top	1.067	1.033	1.048	1.079	1.034	1.048	1.094	1.032	1.057

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.060	1.043	1.056	1.065	1.041	1.056	1.065	1.041	1.045
5′	1.059	1.043	1.056	1.066	1.041	1.056	1.067	1.041	1.046
10′	1.060	1.043	1.056	1.067	1.042	1.056	1.071	1.044	1.047
15′	1.060	1.043	1.056	1.069	1.042	1.058	1.071	1.045	1.048
Top	1.060	1.043	1.056	1.069	1.043	1.059	1.070	1.044	1.047

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	1.071	1.043	1.057	1.059	1.042	1.056	1.063	1.044	1.057
5′	1.070	1.043	1.057	1.060	1.043	1.056	1.063	1.045	1.058
10′	1.071	1.044	1.057	1.061	1.042	1.056	1.063	1.046	1.059
15′	1.070	1.044	1.058	1.061	1.043	1.056	1.063	1.046	1.060
Top	1.070	1.045	1.057	1.060	1.043	1.056	1.062	1.044	1.059

CAPE CANAVERAL RECTIFIERS

GATE NO. I

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860791

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (2/25/91)

Circuit No.	Volts*	Amperes Meter
1	3.3	1.5
2	3.2	1.2
3	2.9	0.42
4	2.9	0.42
5	2.9	0.42
6	2.9	0.42
7	2.9	0.42
8	3.3	1.32

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. III

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860789

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (2/25/91)

Circuit No.	Volts*	Amperes Meter
1	2.6	0.6
2	3.0	0.6
3	2.5	0.03
4	2.5	0.50
5	2.1	0.42
6	2.1	0.42
7	2.0	0.42
8	2.4	1.32

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. II

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860790

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (2/25/91)

Circuit No.	Volts*	Amperes Meter
1	3.1	1.00
2	3.0	0.72
3	2.5	0.18
4	2.5	0.18
5	2.9	0.30
6	2.9	0.30
7	2.9	0.30
8	3.1	0.96

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. IV

Manufacturer:	Universal - 8 Circuits
Model:	ASP-CC
Type:	Constant Current
Serial Number:	860792
Primary:	120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C
Output:	24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (2/25/91)

Circuit No.	Volts*	Amperes Meter
1	3.1	1.00
2	3.0	0.72
3	2.5	0.18
4	2.5	0.18
5	3.0	0.30
6	3.0	0.30
7	3.0	0.30
8	3.1	0.96

* Approximate. Voltage changes with water resistivity/temperature

APPENDIX J: Potential Survey Data for Cape Canaveral
(After Rectifier Adjustment to Lower Current), 1991

CAPE CANAVERAL READINGS
(6/13/91)

GATE NO. 1

DEPTH	A ON	A OFF	A IOP	B ON	B OFF	B IOP	C ON	C OFF	C IOP
Bottom	0.912	0.896	0.907	0.911	0.894	0.906	0.913	0.890	0.909
Middle	0.925	0.909	0.921	0.923	0.903	0.915	0.925	0.896	0.916
Top	0.924	0.911	0.921	0.924	0.904	0.915	0.926	0.897	0.918

DEPTH	D ON	D OFF	D IOP	E ON	E OFF	E IOP	F ON	F OFF	F IOP
Bottom	0.925	0.918	0.926	0.920	0.908	0.916	0.914	0.904	0.910
Middle	0.927	0.920	0.927	0.926	0.913	0.922	0.922	0.909	0.919
Top	0.926	0.920	0.927	0.927	0.915	0.925	0.921	0.910	0.919

DEPTH	G ON	G OFF	G IOP	H ON	H OFF	H IOP	I ON	I OFF	I IOP
Bottom	0.925	0.913	0.921	0.927	0.919	0.927	0.924	0.916	0.924
Middle	0.925	0.912	0.921	0.927	0.918	0.927	0.924	0.917	0.922
Top	0.924	0.912	0.921	0.924	0.918	0.922	0.922	0.915	0.921

CAPE CANAVERAL READINGS
(6/13/91)

GATE NO. 3

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.901	0.890	0.897	0.863	0.843	0.846	0.913	0.889	0.909
Middle	0.924	0.909	0.918	0.913	0.890	0.903	0.925	0.896	0.916
Top	0.924	0.908	0.917	0.915	0.893	0.907	0.926	0.897	0.918

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.923	0.917	0.921	0.914	0.924	0.909	0.917	0.906	0.911
Middle	0.936	0.919	0.922	0.925	0.923	0.921	0.924	0.912	0.918
Top	0.925	0.919	0.921	0.926	0.925	0.921	0.923	0.919	0.919

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.930	0.919	0.927	0.932	0.926	0.930	0.928	0.923	0.926
Middle	0.930	0.920	0.927	0.931	0.923	0.927	0.928	0.920	0.924
Top	0.930	0.920	0.927	0.928	0.922	0.925	0.923	0.917	0.920

CAPE CANAVERAL READINGS
(6/14/91)

GATE NO. 2

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.937	0.924	0.933	0.936	0.908	0.920	0.945	0.936	0.938
Middle	0.953	0.944	0.951	0.952	0.934	0.940	0.956	0.934	0.945
Top	0.958	0.945	0.953	0.953	0.934	0.940	0.957	0.935	0.950

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.965	0.956	0.962	0.977	0.959	0.974	0.968	0.956	0.963
Middle	0.968	0.958	0.967	0.975	0.961	0.969	0.970	0.959	0.966
Top	0.969	0.959	0.968	0.973	0.960	0.968	0.970	0.960	0.968

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.971	0.960	0.968	0.973	0.963	0.969	0.968	0.962	0.968
Middle	0.972	0.960	0.968	0.972	0.964	0.969	0.971	0.964	0.969
Top	0.971	0.959	0.968	0.970	0.963	0.968	0.971	0.963	0.969

CAPE CANAVERAL READINGS
(6/14/91)

GATE NO. 4

	A			B			C		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.965	0.953	0.961	0.969	0.955	0.963	0.945	0.926	0.938
Middle	0.970	0.957	0.963	0.972	0.958	0.964	0.956	0.934	0.945
Top	0.968	0.956	0.962	0.972	0.958	0.965	0.957	0.935	0.950

	D			E			F		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.977	0.966	0.974	0.978	0.966	0.975	0.968	0.959	0.967
Middle	0.980	0.968	0.977	0.981	0.969	0.978	0.968	0.959	0.966
Top	0.979	0.968	0.976	0.981	0.969	0.979	0.969	0.960	0.967

	G			H			I		
DEPTH	ON	OFF	IOP	ON	OFF	IOP	ON	OFF	IOP
Bottom	0.978	0.967	0.974	0.976	0.970	0.974	0.972	0.965	0.971
Middle	0.978	0.967	0.975	0.975	0.968	0.974	0.972	0.965	0.971
Top	0.978	0.969	0.975	0.974	0.967	0.973	0.971	0.965	0.971

CAPE CANAVERAL RECTIFIERS

GATE NO. I

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860791

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (6/14/91)

Circuit No.	Volts*	Amperes Meter
1	2.4	0.5
2	2.5	0.5
3	2.5	0.2
4	2.8	0.2
5	2.6	0.3
6	2.3	0.3
7	2.3	0.3
8	2.5	0.5

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. III

Manufacturer:	Universal - 8 Circuits
Model:	ASP-CC
Type:	Constant Current
Serial Number:	860789
Primary:	120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C
Output:	24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (6/14/91)

Circuit No.	Volts*	Amperes Meter
1	2.5	0.5
2	2.5	0.5
3	2.5	0.2
4	2.5	0.2
5	2.5	0.3
6	2.5	0.3
7	2.5	0.3
8	2.5	0.5

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. II

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860790

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (6/14/91)

Circuit No.	Volts*	Amperes Meter
1	2.3	0.3
2	2.3	0.3
3	2.4	0.2
4	2.3	0.2
5	2.5	0.2
6	2.3	0.2
7	2.3	0.2
8	2.4	0.3

* Approximate. Voltage changes with water resistivity/temperature

CAPE CANAVERAL RECTIFIERS

GATE NO. IV

Manufacturer: Universal - 8 Circuits

Model: ASP-CC

Type: Constant Current

Serial Number: 860792

Primary: 120 VAC, 10 Amperes, Single Phase, 60 Hz, 45°C

Output: 24 Volts/Circuit, 4 Amperes/Circuit

OPERATING DATA (6/14/91)

Circuit No.	Volts*	Amperes Meter
1	2.5	0.3
2	2.5	0.3
3	2.5	0.2
4	2.5	0.2
5	2.5	0.2
6	2.5	0.2
7	2.5	0.2
8	2.5	0.3

* Approximate. Voltage changes with water resistivity/temperature

APPENDIX K: Calculation of Cathodic Protection System Circuit Resistances, Power Requirements, and Cost of Power for Various Alternate Anode Types and Configurations

INPUT VARIABLES	File: USUGPMS.wk1
Structure to be Protected	Chambers of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	432 inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	1728 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	4.6739 ohms
Resistance of All Anodes in Parallel	0.5842 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0451 ohms
Total Circuit Resistance	0.6423 ohms
Total Current Required to Protect this Portion of Structure	0.1728 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.0610
Total Watts Power Required	0.2619
Total KWH's per Year of Operation	2.29
Total Power Cost/Year to Protect this Portion of Structure	$0.16
Total Power Cost over 20 Years to Protect this Portion of Structure	$3.21

INPUT VARIABLES	File: USUGPMB.wk1
Structure to be Protected	Skin Plate of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium Button
Anode Diameter	5 inches
Anode Length	inches
No. of Anodes in Parallel Circuit	32
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	2754 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	162.7907 ohms
Resistance of All Anodes in Parallel	5.0872 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.003225 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	5.0904 ohms
Total Current Required to Protect this Portion of Structure	0.2754 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	2.3519
Total Watts Power Required	0.9253
Total KWH's per Year of Operation	8.11
Total Power Cost/Year to Protect this Portion of Structure	$0.57
Total Power Cost over 20 Years to Protect this Portion of Structure	$11.35

INPUT VARIABLES	File: USDGPMS.wk1
Structure to be Protected	Chambers of U.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	528 inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu–CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu–CuSO4 Ref. Electrode	–0.85 volts
Submerged Structure Surface Area	2112 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm–cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt–Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	3.9073 ohms
Resistance of All Anodes in Parallel	0.4884 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0369 ohms
Total Circuit Resistance	0.5382 ohms
Total Current Required to Protect this Portion of Structure	0.2112 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.0637
Total Watts Power Required	0.3209
Total KWH's per Year of Operation	2.81
Total Power Cost/Year to Protect this Portion of Structure	$0.20
Total Power Cost over 20 Years to Protect this Portion of Structure	$3.94

INPUT VARIABLES	File:USDGPMB.wk1
Structure to be Protected	Skin Plate of U.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium Button
Anode Diameter	5 inches
Anode Length	inches
No. of Anodes in Parallel Circuit	40
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	3640 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	162.7907 ohms
Resistance of All Anodes in Parallel	4.0698 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.00064 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	4.0704 ohms
Total Current Required to Protect this Portion of Structure	0.3640 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	2.2316
Total Watts Power Required	1.1604
Total KWH's per Year of Operation	10.17
Total Power Cost/Year to Protect this Portion of Structure	$0.71
Total Power Cost over 20 Years to Protect this Portion of Structure	$14.23

INPUT VARIABLES	File: dsugpms
Structure to be Protected	Chambers of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	432 inches
No. of Anodes in Parallel Circuit	16
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu–CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu–CuSO4 Ref. Electrode	−0.85 volts
Submerged Structure Surface Area	12960 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm–cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt–Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	4.6739 ohms
Resistance of All Anodes in Parallel	0.2921 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.00645 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0226 ohms
Total Circuit Resistance	0.3211 ohms
Total Current Required to Protect this Portion of Structure	1.2960 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.3662
Total Watts Power Required	2.5294
Total KWH's per Year of Operation	22.16
Total Power Cost/Year to Protect this Portion of Structure	$1.55
Total Power Cost over 20 Years to Protect this Portion of Structure	$31.02

INPUT VARIABLES	File: DSUGPMB
Structure to be Protected	Sill Plate of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium Button
Anode Diameter	5 inches
Anode Length	inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	480 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	162.7907 ohms
Resistance of All Anodes in Parallel	20.3488 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	20.3617 ohms
Total Current Required to Protect this Portion of Structure	0.0480 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.9274
Total Watts Power Required	0.1322
Total KWH's per Year of Operation	1.16
Total Power Cost/Year to Protect this Portion of Structure	$0.08
Total Power Cost over 20 Years to Protect this Portion of Structure	$1.62

INPUT VARIABLES	File: DSDGPMS.wk1
Structure to be Protected	Chambers of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	288 inches
No. of Anodes in Parallel Circuit	16
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	7920 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	6.7028 ohms
Resistance of All Anodes in Parallel	0.4189 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.00645 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0338 ohms
Total Circuit Resistance	0.4592 ohms
Total Current Required to Protect this Portion of Structure	0.7920 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.3137
Total Watts Power Required	1.4864
Total KWH's per Year of Operation	13.02
Total Power Cost/Year to Protect this Portion of Structure	$0.91
Total Power Cost over 20 Years to Protect this Portion of Structure	$18.23

INPUT VARIABLES	File: DSDGPMB.wk1
Structure to be Protected	Sill Plate of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium Button
Anode Diameter	5 inches
Anode Length	inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	480 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	162.7907 ohms
Resistance of All Anodes in Parallel	20.3488 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	20.3617 ohms
Total Current Required to Protect this Portion of Structure	0.0480 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	1.9274
Total Watts Power Required	0.1322
Total KWH's per Year of Operation	1.16
Total Power Cost/Year to Protect this Portion of Structure	$0.08
Total Power Cost over 20 Years to Protect this Portion of Structure	$1.62

INPUT VARIABLES	File:USUGCIS.wk1
Structure to be Protected	Chambers of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	56
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	1728 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	1.1217 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000457 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.3094 ohms
Total Circuit Resistance	1.4316 ohms
Total Current Required to Protect this Portion of Structure	0.1728 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	0.9974
Total Watts Power Required	0.2462
Total KWH's per Year of Operation	2.16
Total Power Cost/Year to Protect this Portion of Structure	$0.15
Total Power Cost over 20 Years to Protect this Portion of Structure	$3.02

INPUT VARIABLES	File:USUGCIB.wk1
Structure to be Protected	Skin Plate of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "K" Button
Anode Diameter	6 inches
Anode Length	3 inches
No. of Anodes in Parallel Circuit	32
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	2808 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	73.1027 ohms
Resistance of All Anodes in Parallel	2.2845 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.0008 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	2.2853 ohms
Total Current Required to Protect this Portion of Structure	0.2808 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.3917
Total Watts Power Required	0.5583
Total KWH's per Year of Operation	4.89
Total Power Cost/Year to Protect this Portion of Structure	$0.34
Total Power Cost over 20 Years to Protect this Portion of Structure	$6.85

INPUT VARIABLES	File:USDGCIS.wk1
Structure to be Protected	Chambers of U.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	72
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	2112 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.8724 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000356 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.2407 ohms
Total Circuit Resistance	1.1134 ohms
Total Current Required to Protect this Portion of Structure	0.2112 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	0.9852
Total Watts Power Required	0.2972
Total KWH's per Year of Operation	2.60
Total Power Cost/Year to Protect this Portion of Structure	$0.18
Total Power Cost over 20 Years to Protect this Portion of Structure	$3.65

INPUT VARIABLES	File:USDGCIB.wk1
Structure to be Protected	Skin Plate of U.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "K" Button
Anode Diameter	6 inches
Anode Length	3 inches
No. of Anodes in Parallel Circuit	40
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	inches
Anode Pipe Protection Wall Thickness	inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	3640 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	73.1027 ohms
Resistance of All Anodes in Parallel	1.8276 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.00064 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	1.8282 ohms
Total Current Required to Protect this Portion of Structure	0.3640 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.4155
Total Watts Power Required	0.7360
Total KWH's per Year of Operation	6.45
Total Power Cost/Year to Protect this Portion of Structure	$0.45
Total Power Cost over 20 Years to Protect this Portion of Structure	$9.03

INPUT VARIABLES	File:dsugcls.wk1
Structure to be Protected	Chambers of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	112
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	12,960 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.5608 ohms
Single Anode Lead Wire Rislstance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000229 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.1547 ohms
Total Circuit Resistance	0.7158 ohms
Total Current Required to Protect this Portion of Structure	1.2960 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.6777
Total Watts Power Required	3.1061
Total KWH's per Year of Operation	27.21
Total Power Cost/Year to Protect this Portion of Structure	$1.90
Total Power Cost over 20 Years to Protect this Portion of Structure	$38.09

INPUT VARIABLES	File:DSUGCIB.wk1
Structure to be Protected	Sill Plate of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "K" Button
Anode Diameter	6 Inches
Anode Length	3 Inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	Inches
Anode Pipe Protection Wall Thickness	Inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	480 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	73.1027 ohms
Resistance of All Anodes in Parallel	9.1378 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.0032 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	9.1410 ohms
Total Current Required to Protect this Portion of Structure	0.0480 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.1888
Total Watts Power Required	0.0815
Total KWH's per Year of Operation	0.71
Total Power Cost/Year to Protect this Portion of Structure	$0.05
Total Power Cost over 20 Years to Protect this Portion of Structure	$1.00

INPUT VARIABLES	File:DSDGCIS.wk1
Structure to be Protected	Chambers of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	80
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	7,920 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.7852 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.00032 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.2166 ohms
Total Circuit Resistance	1.0021 ohms
Total Current Required to Protect this Portion of Structure	0.7920 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.5437
Total Watts Power Required	1.7465
Total KWH's per Year of Operation	15.30
Total Power Cost/Year to Protect this Portion of Structure	$1.07
Total Power Cost over 20 Years to Protect this Portion of Structure	$21.42

INPUT VARIABLES

File:DSDGCIB.wk1

Structure to be Protected	Sill Plate of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "K" Button
Anode Diameter	6 Inches
Anode Length	3 Inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	Inches
Anode Pipe Protection Wall Thickness	Inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	480 sq. ft.
Coating Efficiency	95.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS

Single Anode Circuit Resistance	73.1027 ohms
Resistance of All Anodes in Parallel	9.1378 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.0032 ohms
Risistance of Single Hole in Anode Pipe Protector	0.0000 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0000 ohms
Total Circuit Resistance	9.1410 ohms
Total Current Required to Protect this Portion of Structure	0.0480 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	1.1888
Total Watts Power Required	0.0815
Total KWH's per Year of Operation	0.71
Total Power Cost/Year to Protect this Portion of Structure	$0.05
Total Power Cost over 20 Years to Protect this Portion of Structure	$1.00

INPUT VARIABLES	File: USUGPMS5.wk1
Structure to be Protected	Chambers of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	432 inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu−$CuSO_4$ Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu−$CuSO_4$ Ref. Electrode	−0.85 volts
Submerged Structure Surface Area	1728 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm−cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt−Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	4.6739 ohms
Resistance of All Anodes in Parallel	0.5842 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0451 ohms
Total Circuit Resistance	0.6423 ohms
Total Current Required to Protect this Portion of Structure	1.7280 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	2.0598
Total Watts Power Required	5.0848
Total KWH's per Year of Operation	44.54
Total Power Cost/Year to Protect this Portion of Structure	$3.12
Total Power Cost over 20 Years to Protect this Portion of Structure	$62.36

INPUT VARIABLES	File: USDGPMS5.wk1
Structure to be Protected	Chambers of U.S.S./D.S.G. Lock & Dam Miter Gate •
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	528 inches
No. of Anodes in Parallel Circuit	8
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	2112 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	3.9073 ohms
Resistance of All Anodes in Parallel	0.4884 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.0129 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0369 ohms
Total Circuit Resistance	0.5382 ohms
Total Current Required to Protect this Portion of Structure	2.1120 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	2.0867
Total Watts Power Required	6.2960
Total KWH's per Year of Operation	55.15
Total Power Cost/Year to Protect this Portion of Structure	$3.86
Total Power Cost over 20 Years to Protect this Portion of Structure	$77.21

INPUT VARIABLES	File: DSUGPMS5.wk1
Structure to be Protected	Chambers of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	432 inches
No. of Anodes in Parallel Circuit	16
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	12960 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	4.6739 ohms
Resistance of All Anodes in Parallel	0.2921 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.00645 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0226 ohms
Total Circuit Resistance	0.3211 ohms
Total Current Required to Protect this Portion of Structure	12.9600 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	5.1119
Total Watts Power Required	94.6423
Total KWH's per Year of Operation	829.07
Total Power Cost/Year to Protect this Portion of Structure	$58.03
Total Power Cost over 20 Years to Protect this Portion of Structure	$1,160.69

INPUT VARIABLES	File: DSDGPMS5.wk1
Structure to be Protected	Chambers of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Precious Metal Oxide (Ceramic) Coated Titanium
Anode Diameter	0.125 inches
Anode Length	288 inches
No. of Anodes in Parallel Circuit	16
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	2.58 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	7920 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	6.7028 ohms
Resistance of All Anodes in Parallel	0.4189 ohms
Single Anode Lead Wire Risistance	0.1032 ohms
Resistance of All Anode Lead Wires in Parallel	0.00645 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.0338 ohms
Total Circuit Resistance	0.4592 ohms
Total Current Required to Protect this Portion of Structure	7.9200 amperes
Voltage Required to Produce Any Current Flow	0.9500 volts
Total Voltage Required to Produce Estimated Current Required	4.5870
Total Watts Power Required	51.8986
Total KWH's per Year of Operation	454.63
Total Power Cost/Year to Protect this Portion of Structure	$31.82
Total Power Cost over 20 Years to Protect this Portion of Structure	$636.48

INPUT VARIABLES	File:USUGCIS5.wk1
Structure to be Protected	Chambers of U.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	56
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	1728 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	1.1217 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000457 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.3094 ohms
Total Circuit Resistance	1.4316 ohms
Total Current Required to Protect this Portion of Structure	1.7280 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	3.2237
Total Watts Power Required	7.9580
Total KWH's per Year of Operation	69.71
Total Power Cost/Year to Protect this Portion of Structure	$4.88
Total Power Cost over 20 Years to Protect this Portion of Structure	$97.60

INPUT VARIABLES	File:USDGCIS5.wk1
Structure to be Protected	Chambers of U.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	72
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	2112 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.8724 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000356 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.2407 ohms
Total Circuit Resistance	1.1134 ohms
Total Current Required to Protect this Portion of Structure	2.1120 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	3.1016
Total Watts Power Required	9.3579
Total KWH's per Year of Operation	81.98
Total Power Cost/Year to Protect this Portion of Structure	$5.74
Total Power Cost over 20 Years to Protect this Portion of Structure	$114.77

INPUT VARIABLES	File:DSUGCIS5.wk1
Structure to be Protected	Chambers of D.S.S./U.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	112
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	12,960 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.5608 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.000229 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.1547 ohms
Total Circuit Resistance	0.7158 ohms
Total Current Required to Protect this Portion of Structure	12.9600 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	10.0265
Total Watts Power Required	185.6342
Total KWH's per Year of Operation	1,626.16
Total Power Cost/Year to Protect this Portion of Structure	$113.83
Total Power Cost over 20 Years to Protect this Portion of Structure	$2,276.62

INPUT VARIABLES	File:DSDGCIS5.wk1
Structure to be Protected	Chambers of D.S.S./D.S.G. Lock & Dam Miter Gate
Anode Type	Hi-Silicon Chromium Cast Iron Type "G" Segmented
Anode Diameter	2 inches
Anode Length	9 inches
No. of Anodes in Parallel Circuit	80
Anode Lead Wire Size	14 AWG
Average Anode Lead Wire Length	40 feet
Anode Lead Wire Resistance/Mft.	0.64 ohms
Anode Pipe Protector Perforated Hole Diameter	1.5 inches
Anode Pipe Protection Wall Thickness	0.3 inches
No. of Perforated Holes/Ft. of Anode Pipe Protector	18 holes
Anode Native Potential/Cu-CuSO4 Ref. Electrode	-0.1 volts
Desired Polarized Cathode Protective Level/Cu-CuSO4 Ref. Electrode	-0.85 volts
Submerged Structure Surface Area	7,920 sq. ft.
Coating Efficiency	50.0%
Electrolyte Resistivity	3500 ohm-cm
Rectifier AC to DC Power Conversion Efficiency	70.0%
A.C. Power Cost per Kilowatt-Hour	$0.070
Estimated Current Density Required for C.P./Bare Sq. Ft. of Submerged Steel	0.002 amps/sq.ft.

CALCULATED RESULTS	
Single Anode Circuit Resistance	62.8140 ohms
Resistance of All Anodes in Parallel	0.7852 ohms
Single Anode Lead Wire Risistance	0.0256 ohms
Resistance of All Anode Lead Wires in Parallel	0.00032 ohms
Risistance of Single Hole in Anode Pipe Protector	233.9285 ohms
Total Resistance of All Holes in Parallel for All Anodes in Parallel	0.2166 ohms
Total Circuit Resistance	1.0021 ohms
Total Current Required to Protect this Portion of Structure	7.9200 amperes
Voltage Required to Produce Any Current Flow	0.7500 volts
Total Voltage Required to Produce Estimated Current Required	8.6866
Total Watts Power Required	98.2826
Total KWH's per Year of Operation	860.96
Total Power Cost/Year to Protect this Portion of Structure	$60.27
Total Power Cost over 20 Years to Protect this Portion of Structure	$1,205.34

APPENDIX L: Anode Power Consumption Report

Contract # DACA88-87-0004

Anode Power Test Study

A Comparison of the HSCICB K-6 Button Anode

and

the LSA-12-5-CC Flat Ceramic Disk Anode

4 and 8 foot Strip Anodes were also compared

The purpose of this study is to determine the power consumption required for various surfaced mounted impressed current anode configurations. The anodes tested were the Duriron Model K-6 High Silicon Cast Iron Chromium Bearing Button Anode, the CerAnode Technologies Models LSA-12-5-CC (Ceramic Coated Titanium Flat Disk with integral shield), Model #CAS-4 (4 Foot Strip Anode) and Model #CAS-8 (8 Foot Strip Anode).

A 12 x 12 foot wooden raft with a steel bottom was constructed using sheet metal, 2x4's and four 55 gallon barrels, one per corner to keep it afloat. The 55 gallon barrels were painted and were electrically isolated from the steel bottom of the raft. The barrels were arranged with levers on the sides of the raft in order to adjust the raft depth so that the steel surface would be 8-12 inches under water. Care was taken in the construction of the raft to keep it free from any galvanized screws, bolts or nuts. The steel was unaffected by any galvanic influences. No metallic paints of any kind were used in the construction of the raft. The steel bottom of the raft was painted except for concentric circular 5/8 inch wide stripes every six inches from the center. This resulted in about 10% of the steel surface being uncoated. A small section in the middle of the raft was designed so that it could be taken in and out easily in order to install different anode shapes for the test. 23 reference cells were arranged in a V-shape from the center out to two of the corners of the raft for taking ON and OFF POTENTIAL readings at various distances from the anode. These were arranged so that every other one was close to a bare metal concentric stripe and the other at the painted portion of the steel surface.

The raft was located on the lake at Hilltop Resources north of Fairborn, Ohio. It was positioned on the lake approximately 75 feet from the shore. The water depth at that point was approximately 35 feet. Cables from the 22 secondary reference cells, the primary reference cell, the anode and the cathode were routed to a control box on the shore where the appropriate terminal strips rheostat and battery were located. The water resistivity was approximately 2000 ohm/centimeters and the temperature was relatively constant (25 degrees C +/- 5, usually +/- 2). As mentioned above, in addition to the 22 secondary reference cells located on the raft, a primary permanent reference cell (Harco Model IHRP 801) was located at a far corner of the raft and all the reference cells were checked in relationship to that cell when the anode power was off. This allowed normalization of the data of the different reference cells positioned on the raft. The secondary reference cells were not of the same quality as the primary reference cell but comparative testing established each cells integrity. They all remained trustworthy. Data from cells 12 and 13 were not used in the power test analysis since they did not fit properly.

DATA PRESENTATION

Figures L-1 through L-7 represent the basic test data for this report. Figures L-1 and L-3 contain a summary of the data generated for the LSA Flat Ceramic Disk Anode. Figures L-2, L-4 and L-5 provide data for the Button K-6 Anode, and Figures L-6 and L-7 for the 4 and 8 foot Strip Anodes respectively. ON POTENTIAL, OFF POTENTIAL, DECAY POTENTIAL, POTENTIAL SHIFT, ANODE VOLTAGE, ANODE CURRENT, CIRCUIT RESISTANCE and POWER is given. The potential data was recorded from each of the reference cells positioned across the raft's steel bottom. The anode current was increased until a potential shift of approximately 100mV was obtained at the raft's corner for the data recorded in Figures L-1 and L-2. Larger shifts are produced in Figures L-3 through L-7.

As would be expected, both the ON POTENTIALS and the OFF POTENTIALS get larger as they get closer to the anode but the ON POTENTIALS to a much greater extreme. The OFF POTENTIAL measurement gets larger because the cathode potential is truly more negative closer to the anode but the ON POTENTIAL measurement gets larger because the "IR" measurement error increases close to the anode. This shows clearly that OFF POTENTIAL measurement, or preferably INSTANT OFF POTENTIAL measurement, as opposed to ON POTENTIAL measurement is most important when surveying locks and dams. The IR errors associated with the ON POTENTIAL measurement distort the real potential measurement considerably as you get closer to the anode.

The equipotential data as observed in the OFF POTENTIAL readings and the POTENTIAL SHIFTS are quite uniform considering the anode size, the raft size and the anode power. On the other hand, the raft is remote and isolated from other current sinks giving a picture of the actual power required to protect the raft surface.

The data seems to indicate that the potential shift achieved on the surface of the raft's steel bottom does not just relate to the current but also to the power. In other words, the net shift is significantly related to the power expended through the anode and not just the current passing through it to the cathode. Figure L-1 shows potential shift data for the flat disk LSA when powered with a current of 83mA at 13 volts. The resultant power is 1.07 watts. Figure L-2 shows data for a K-6 Button anode with a current of 198mA at 6.33 volts resulting in a power dissipation of 1.25 watts. Both anodes produce essentially the same amount of shift for the same amount of power even though the currents and voltages are quite different.

Figures L-3 and L-4 give data for the LSA and the K-6 at higher power settings. Since the K-6 is a significantly lower resistance anode, due to its geometry, the power difference begins to show up at a higher power setting but it is not dramatic. 3.5 watts of power dissipated through the K-6 produces a slightly higher potential shift than 4.5 watts of power through the LSA. Considering the difference in circuit resistances between the two anodes (140 ohms verses 24 ohms), the power differences (4.5 watts verses 3.6 watts) are not all that significant.

When the K-6 is compared with the 4 foot strip anode in Figures L5 and L6, it is evident that the Strip Anode is significantly superior in that it produces a considerably greater potential shift with less power. In this case, an average potential shift of 167mV is produced with 4.4 watts of power using the K-6 Anode and an average potential shift of 235mV is produced with only 3.5 watts of power using the 4 foot Strip Anode.

The 8 foot Strip Anode data is even more dramatic (Figure L-7). With this anode only 3.3 watts of power produces an average 330 millivolts shift and in this case lowers the cathode potential well below the -0.85 criteria.

CONCLUSION

The power consumed by either the button anode or the flat disk anode is quite small compared to the power usually associated with cathodic protection. The reason for this is probably because the anode is mounted on the structure and is therefore very close to the structure. This also holds true for the strip anodes. Therefore, the amount of power required to protect a surface using any of the surface mounted anode styles is less compared to anodes that are mounted remote from the structure. This becomes evident when sites using these anodes are examined in terms of their power consumption. Cordell Hull, for example, utilizes only 39 watts to protect the entire gate structure which is 44 x 45 feet including the bare metal chains. The 12 gates at Palmetto Bend Dam in Texas, each gate being approximately 35 x 24 feet, utilizes only 30 watts of power to protect all 12 gates. The anodes are efficiently providing 1/2 milliampere per square foot of surface area to those gates. More power will be required as the coating ages. The flat ceramic anode disk as well as the button anode is designed to work in tandem together with other anodes of the same type. The by-product is a superior current distribution over the structure.

Whenever a structure requires a higher current for protection than the 8 foot strip anode or anodes of that nature should be chosen.

Alternate anode designs are under present consideration such as a larger LSA. A modified version of the strip anode that was tested has already been built and will soon be tested and compared to the above results.

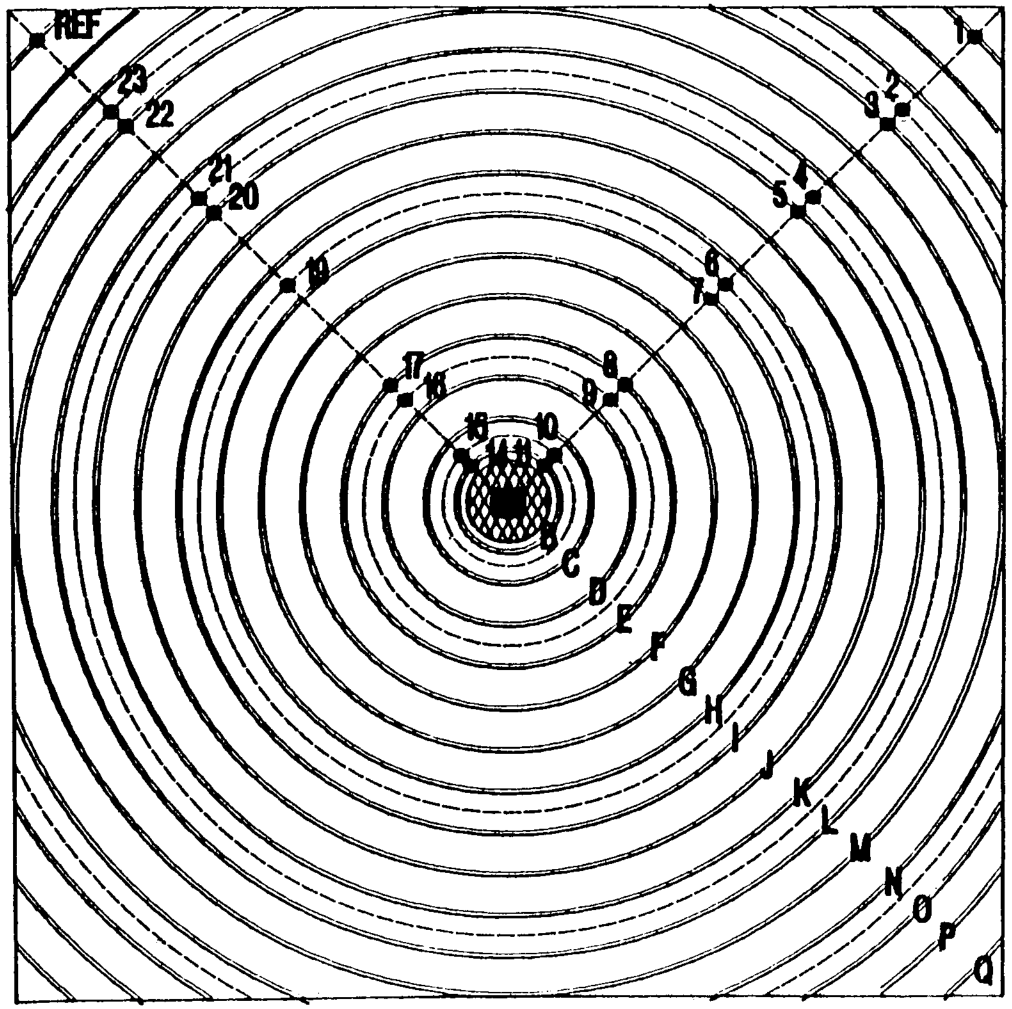
LSA-12-R-5-CC POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	726	680	565	115
23	725	680	565	115
22	726	679	565	114
21	731	683	565	118
20	731	681	565	116
19	740	683	565	118
18	***	***	***	***
17	810	699	565	134
16	835	701	565	136
15	1148	753	565	188
14	1391	774	565	209
13	****	***	***	***
AVERAGE	0856	701	565	136

CONCENTRIC BARE METAL CIRCULAR STRIPES "B" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	684	662	565	097
2	716	674	565	109
3	723	682	565	117
4	727	681	565	116
5	728	681	565	116
6	739	684	565	119
7	742	685	565	120
8	804	695	565	130
9	854	701	565	136
10	1213	750	565	185
11	1455	789	565	224
12	****	***	***	***
AVERAGE	0853	699	565	134

ANODE CURRENT	0.083	AMPERES
ANODE VOLTAGE	13	VOLTS
CIRCUIT RES.	157	OHMS
POWER	1.07	WATTS

6/30/89

Figure L-1. Potential Shift Data for Flat Disk LSA, Current of 83mA at 13V.

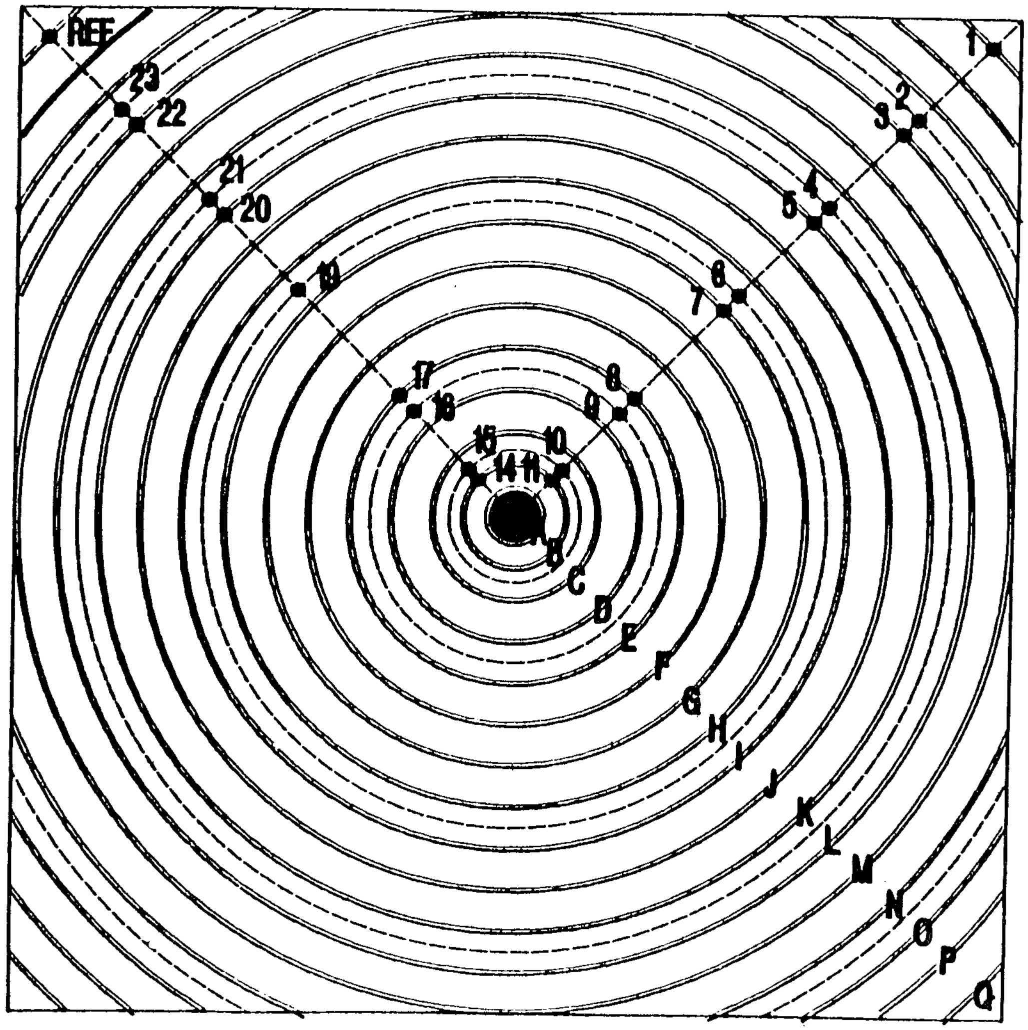
HSCICB K-6 ANODE POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	740	678	565	113
23	730	673	565	108
22	730	672	565	107
21	732	674	565	109
20	734	677	565	112
19	742	677	565	112
18	***	***	***	***
17	811	697	565	132
16	838	697	565	132
15	1158	735	565	170
14	1336	754	565	189
13	****	***	***	***
AVERAGE	0855	693	565	128

CONCENTRIC BARE METAL CIRCULAR STRIPES "A" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

A = 4" RADIUS
B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	735	677	565	112
2	736	676	565	111
3	735	675	565	110
4	739	676	565	111
5	741	678	565	113
6	756	680	565	115
7	761	681	565	116
8	838	700	565	135
9	878	706	565	141
10	1221	724	565	159
11	1397	744	565	179
12	****	***	***	***
AVERAGE	0867	692	565	128

ANODE CURRENT	0.198	AMPERES
ANODE VOLTAGE	6.33	VOLTS
CIRCUIT RES.	32	OHMS
POWER	1.25	WATTS

8/17/89

Figure L-2. Potential Shift Data for K-6 Button Anode, Current of 198mA at 6.33V.

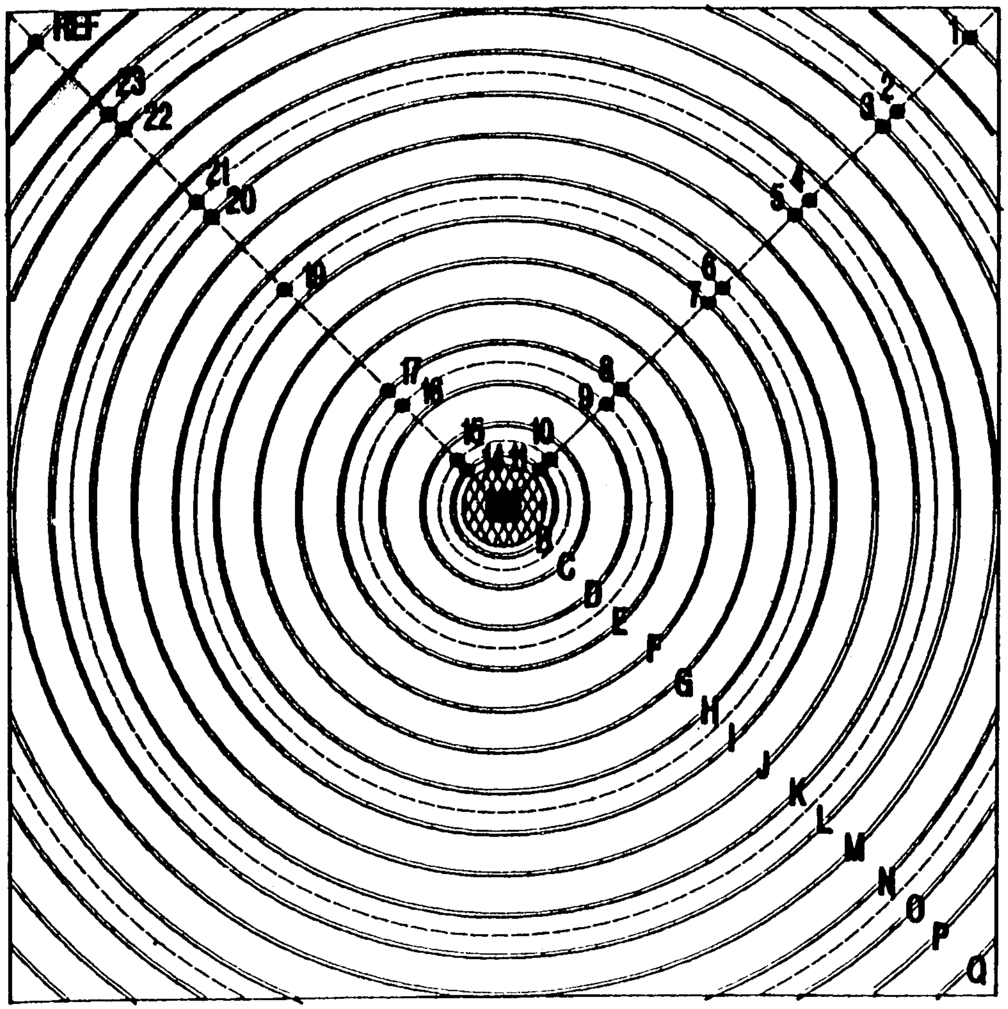
LSA-12-R-5-CC POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	801	701	565	136
23	799	701	565	136
22	799	697	565	132
21	800	699	565	134
20	801	699	565	134
19	815	704	565	139
18	***	***	***	***
17	946	722	565	157
16	999	728	565	163
15	1518	749	565	184
14	1740	770	565	205
13	****	***	***	***
AVERAGE	1002	717	565	152

CONCENTRIC BARE METAL CIRCULAR STRIPES "B" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	788	697	565	132
2	796	707	565	142
3	787	696	565	131
4	793	704	565	139
5	798	704	565	139
6	823	700	565	135
7	833	701	565	136
8	963	714	565	149
9	1016	718	565	153
10	1559	757	565	192
11	1943	777	565	212
12	****	***	***	***
AVERAGE	1009	716	565	151

ANODE CURRENT	0.179	AMPERES
ANODE VOLTAGE	25	VOLTS
CIRCUIT RES.	140	OHMS
POWER	4.47	WATTS

7/13/89

Figure L-3. Potential Shift Data for Flat Disk LSA, Current of 179mA at 25V.

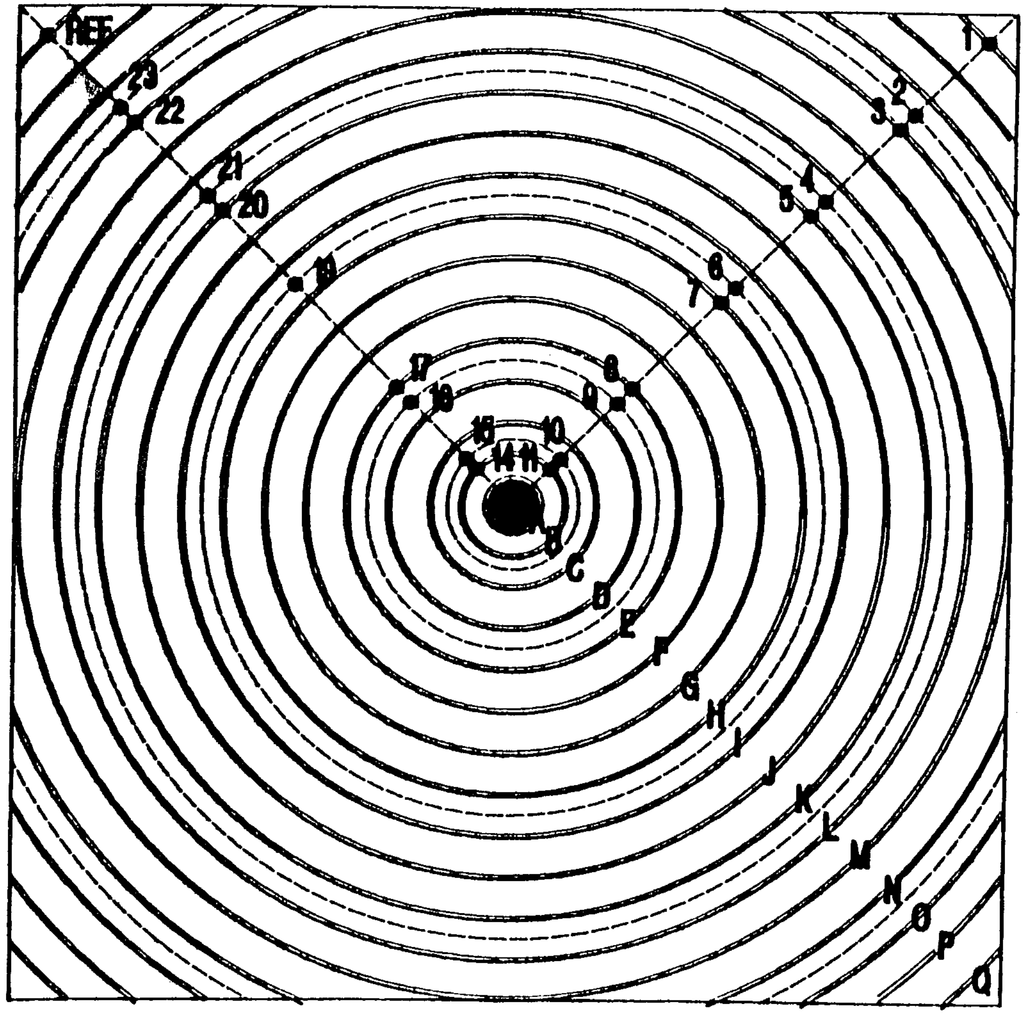
HSCICB K-6 ANODE POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	836	710	565	145
23	822	705	565	140
22	821	705	565	140
21	821	706	565	141
20	827	706	565	141
19	841	715	565	150
18	***	***	***	***
17	965	721	565	156
16	1007	761	565	196
15	1427	750	565	185
14	1699	757	565	192
13	****	***	***	***
AVERAGE	1007	724	565	159

CONCENTRIC BARE METAL CIRCULAR STRIPES "A" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

- A = 4" RADIUS
- B = 7.5" RADIUS
- C = 12" RADIUS
- D THROUGH Q ARE EVERY 6" THEREAFTER (18", 24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	826	710	565	145
2	827	709	565	144
3	826	707	565	142
4	834	709	565	144
5	838	711	565	146
6	865	709	565	144
7	872	717	565	152
8	1008	721	565	156
9	1068	726	565	161
10	1549	761	565	196
11	1772	761	565	196
12	****	***	***	***
AVERAGE	1026	721	565	157

ANODE CURRENT	0.382	AMPERES
ANODE VOLTAGE	9.31	VOLTS
CIRCUIT RES.	24	OHMS
POWER	3.6	WATTS

7/31/89

Figure L-4. Potential Shift Data for K-6 Button Anode, Current of 382mA, 9.31V.

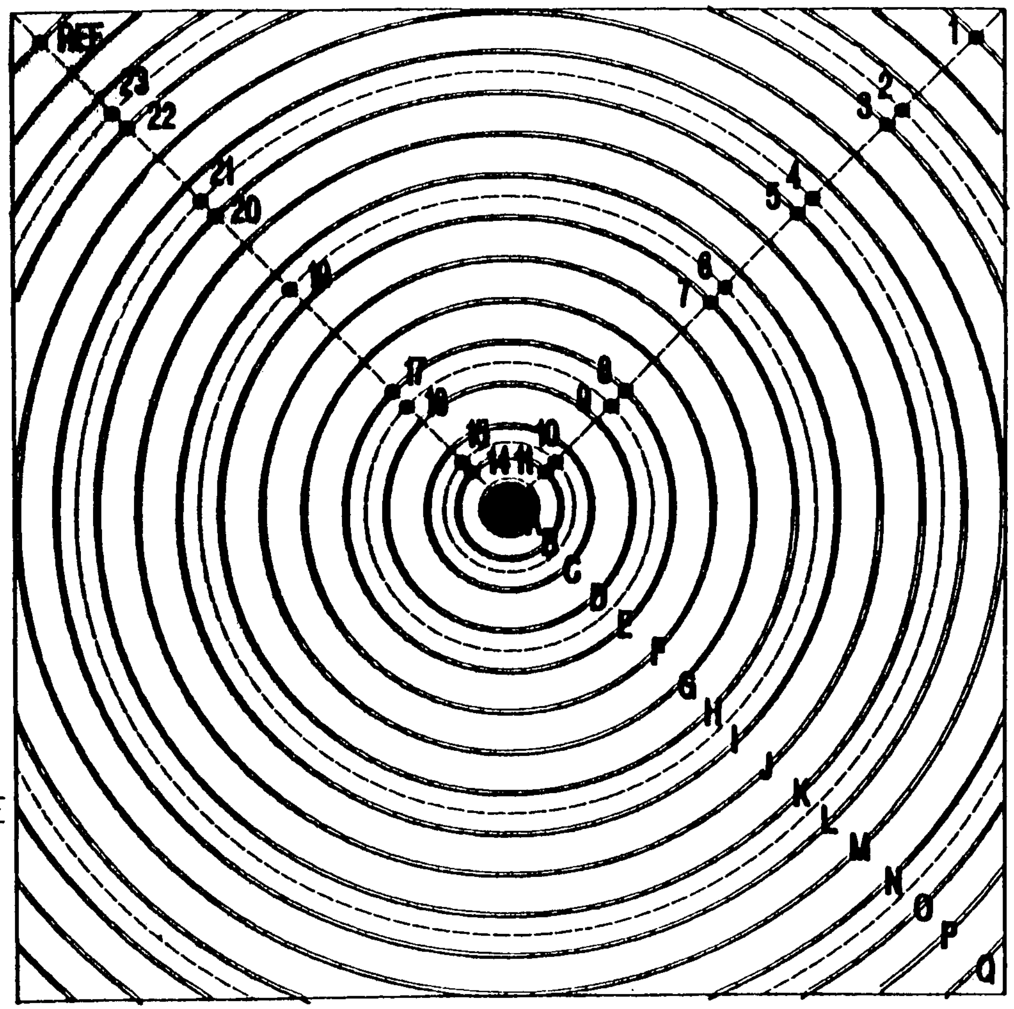
HSCICB K-6 ANODE POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	860	717	565	152
23	845	712	565	147
22	845	711	565	146
21	849	717	565	152
20	851	717	565	156
19	868	721	565	156
18	***	***	***	***
17	1010	740	565	175
16	1061	741	565	176
15	1555	766	565	201
14	1856	775	565	201
13	****	***	***	***
AVERAGE	1060	732	565	167

CONCENTRIC BARE METAL CIRCULAR STRIPES "A" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

A = 4" RADIUS
B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	850	719	565	154
2	850	721	565	156
3	851	715	565	150
4	858	718	565	153
5	862	716	565	151
6	892	722	565	157
7	900	723	565	158
8	1050	732	565	167
9	1126	737	565	172
10	1668	773	565	208
11	1928	784	565	219
12	****	***	***	***
AVERAGE	1076	733	565	168

ANODE CURRENT	0.435	AMPERES
ANODE VOLTAGE	10.19	VOLTS
CIRCUIT RES.	23	OHMS
POWER	4.43	WATTS

7/28/89

Figure L-5. Potential Shift Data for K-6 Button Anode, Current of 435mA at 10.19V.

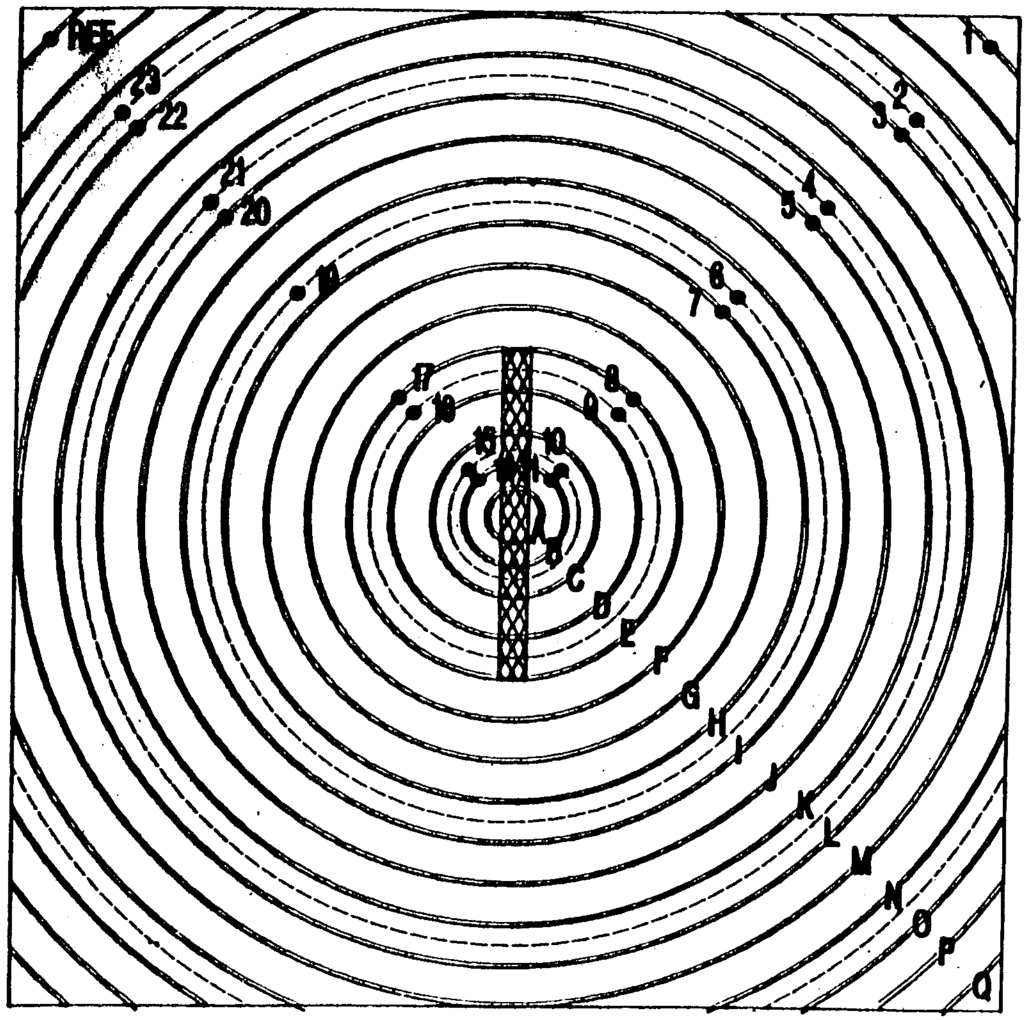
4 FOOT STRIP ANODE POWER TEST---EQUIPOTENTIAL DATA

*POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	893	777	565	212
23	888	772	565	207
22	885	775	565	210
21	897	773	565	203
20	897	772	565	207
19	919	776	565	211
18	***	***	***	***
17	1058	802	565	237
16	1100	801	565	236
15	1316	833	565	268
14	1452	954	565	289
13	2183.	869	565	304
AVERAGE	1135	800	565	235

CONCENTRIC BARE METAL CIRCULAR STRIPES "A" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

A = 4" RADIUS
B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	884	777	565	212
2	885	774	565	209
3	880	774	565	209
4	900	783	565	218
5	908	783	565	218
6	941	786	565	221
7	956	787	565	222
8	1103	800	565	235
9	1171	803	565	238
10	1401	841	565	276
11	1456	847	565	282
12	1334	841	565	276
AVERAGE	1060	800	565	235

ANODE CURRENT	0.320	AMPERES
ANODE VOLTAGE	10.99	VOLTS
CIRCUIT RES.	34	OHMS
POWER	3.52	WATTS

6/27/89

Figure L-6. Potential Shift Data for 4-ft Strip Anode, Current of 320mA at 10.99V.

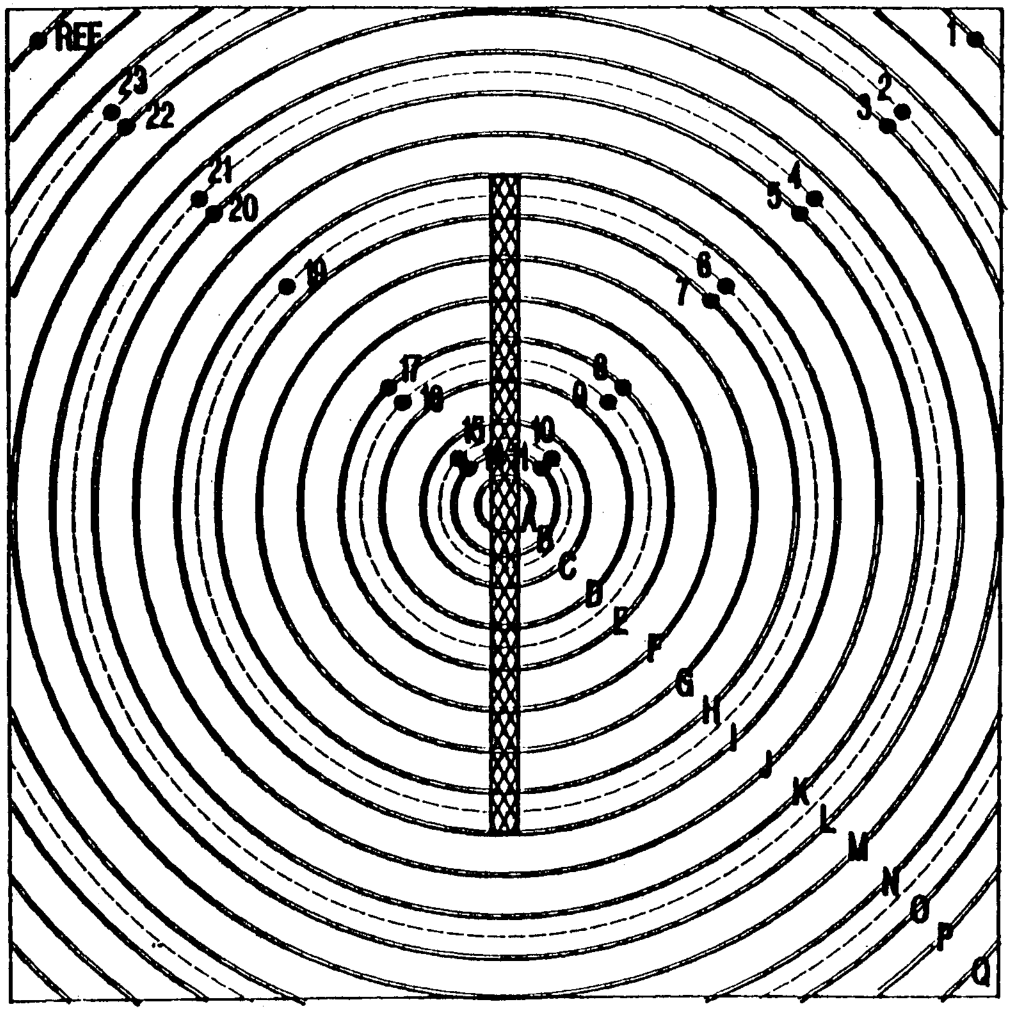
8 FOOT STRIP ANODE POWER TEST---EQUIPOTENTIAL DATA

POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
REF	1106	887	565	322
23	1078	885	565	320
22	1078	886	565	321
21	1094	884	565	319
20	1101	884	565	319
19	1126	879	565	314
18	***	***	***	***
17	1253	896	565	331
16	1278	889	565	324
15	1371	916	565	351
14	1444	924	565	359
13	****	***	***	***
AVERAGE	1193	893	565	328

CONCENTRIC BARE METAL CIRCULAR STRIPES "A" THROUGH "Q" 5/8" WIDE ARE USED TO SIMILATE A DEGRADED COATING SYSTEM. THEIR LOCATIONS ARE:

A = 4" RADIUS
B = 7.5" RADIUS
C = 12" RADIUS
D THROUGH Q ARE EVERY 6" THEREAFTER (18",24", ETC.)



POTENTIALS

CELL	ON	OFF	DECAY	SHIFT
1	1069	887	565	322
2	1083	892	565	327
3	1089	884	565	319
4	1111	891	565	326
5	1116	893	565	328
6	1147	890	565	325
7	1156	885	565	320
8	1271	899	565	334
9	1311	905	565	340
10	1419	917	565	352
11	1453	920	565	355
12	****	***	***	***
AVERAGE	1202	897	565	332

ANODE CURRENT	0.410	AMPERES
ANODE VOLTAGE	7.99	VOLTS
CIRCUIT RES.	20	OHMS
POWER	3.28	WATTS

6/28/89

Figure L-7. Potential Shift Data for 8-ft Strip Anode, Current of 410mA at 7.99V.

APPENDIX M: Total Installation Cost Comparison of Ceramic Anode Systems With HSCBCI Systems

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE USSUSGCP

Quant.	Item No.	Unit	Upstream Surface of Upstream Gates (Both Leafs) Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			HSCCI Anode Assemblies:				
8	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 7 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	$519.29	$4,154.32	I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Plastic Compression Washers.	$301.98	$9,663.36	I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:				
32	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2 " O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart. Unit price includes Items No. 3, 4, 5, & 7 *	$55.00	$1,760.00	I-5B	A
32	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*		I-5B	A
32	5	Each	Anode mounting hole Plastic Plug	*		I-5B	A
32	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	$5.16	$165.12	I-5B	A
32	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	*		I-5B	A
32	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$2,464.00	I-5B	K
			String Anode Metallic Protection and Support Components				
4	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 2&4
4	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R,Q, Note 1
56	11	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L,Q K
8	12	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	13	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	14	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: USSUSGCP

Upstream Surface of Upstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			String Anode Perforated Plastic Pipe Protectors				
8	15	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
56	17	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$257.60		
8	18	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
112	19	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$1,400.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	20	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	21	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	22	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	22	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	23	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	24	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$4,230.67		

$32,435.11 TOT. MAT'LS. COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			HSCCI Anode Assemblies:							
8	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 7 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	8.0	24.0	16.0	16.0		I-5 I-7 I-1	I "A-A" "B-B"
32	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Includes Items No. 2, 3, 4, 5, 6, 7 & 8 **	32.0	96.0	64.0	64.0		I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:							
32	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2 " O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart.	**	**	**	**		I-5B	A
32	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	**	**	**	**		I-5B	A
32	5	Each	Anode mounting hole Plastic Plug	**	**	**	**		I-5B	A
32	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	**	**	**	**		I-5B	A
32	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	**	**	**	**		I-5B	A
32	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	**	**	**	**		I-5B	K
			String Anode Metallic Protection and Support Components	4.0	12.0	8.0	8.0			
4	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.* Includes Items No. 9, 10, 11, 12, 13 & 14 ***						I-7 I-6 I-1	K L Notes 2&4
4	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	***	***	***	***		I-6 I-1	R,Q, Note 1
56	11	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	***	***	***	***		I-6 I-7	L,Q K
8	12	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	***	***	***	***		I-6	N
8	13	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	***	***	***	***		I-6	N
8	14	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	***	***	***	***		I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			String Anode Perforated Plastic Pipe Protectors	8.0	24.0	16.0	16.0			
8	15	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****						I-7 I-9 I-6	K X L,M
56	16	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	****	****	****	****			
8	17	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	****	****	****	****		I-6	L
112	18	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	****	****	****	****		I-6 I-7	L K
			Miscellaneous Hardware	8.0	24.0	16.0	16.0			
8	19	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes. Includes Items No.19, 20, 21, 22 & 23*****						I-5	F
8	20	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	*****	*****	*****	*****		I-5	F
1	21	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	*****	*****	*****	*****			
1	22	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	*****	*****	*****	*****		I-8A	
1	23	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.	*****	*****	*****	*****		I-6 I-7	
			Total of Man-Hours for each labor classification:	60	180	120	120			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$4,500	$10,800	$6,600	$5,400			
			10.0% Contigency for weather delays, etc.:	$450	$1,080	$660	$540			

$30,030.00 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: OSSUSGCP

Downstream Surface of Upstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			HSCCI Anode Assemblies:				
16	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 7 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	$519.29	$8,308.64	I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Plastic Compression Washers. *Install 4 each at bottom girder on both gates*	$301.98	$2,415.84	I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:				
8	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2 " O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart. Includes Items No. 3, 4, 5 & 7 *	$55.00	$440.00	I-5B	A
8	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*	*	I-5B	A
8	5	Each	Anode mounting hole Plastic Plug	*	*	I-5B	A
8	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	$5.16	$41.28	I-5B	A
8	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	*	*	I-5B	A
8	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			String Anode Metallic Protection and Support Components				
12	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 2&4
8	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
4	11	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*	$195.00	$780.00	I-2	Note 1
16	12	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$140.80	I-6 I-7	L,Q K
16	13	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6	N
16	14	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6	N
16	15	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00	I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES

PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: DS3USGCP

Downstream Surface of Upstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			String Anode Perforated Plastic Pipe Protectors				
16	16	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$3,152.00	I-7 I-9 I-6	K X L,M
112	17	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$515.20		
16	18	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$244.80	I-6	L
224	19	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$2,800.00	I-6 I-7	L K
			Miscellaneous Hardware				
16	20	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$72.00	I-5	F
16	21	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$61.76	I-5	F
1	22	Lot	Conduit. Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	23	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)	$929.00	$929.00	I-8A	
1	24	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	$2,361.00	$2,361.00	I-6 I-7	
1	25	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15%	$4,043		
					$30,994.57 TOT. MAT'LS. COST ESTIMATE		

Downstream Surface of Upstream Gates (Both Leafs)										Dwg. Reference	
Quant	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs		Sheet No.	Detail Nos.
			HSCCI Anode Assemblies:								
16	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 7 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	16.0	32.0	32.0	32.0			I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Plastic Compression Washers. *Install 4 each at bottom girder on both gates.* Includes Items No. 2, 3, 4, 5, 6, 7 & 8 *	8.0	16.0	16.0	16.0			I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:								
8	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2 " O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart.	*	*	*	*			I-5B	A
8	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*	*	*	*			I-5B	A
8	5	Each	Anode mounting hole Plastic Plug	*	*	*	*			I-5B	A
8	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	*	*	*	*			I-5B	A
8	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	*	*	*	*			I-5B	A
8	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*			I-5B	K
			String Anode Metallic Protection and Support Components:								
12	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates* Includes Items No. 9, 10, 11, 12, 13, 14 & 15 **	12.0	24.0	24.0	24.0			I-7 I-6 I-1	K L Notes 2&4
8	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	**	**	**	**			I-6 I-1	R,Q, Note 1
4	11	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*	**	**	**	**				
16	12	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**			I-6 I-7	L,Q K
16	13	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**			I-6	N
16	14	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**			I-6	N
16	15	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**			I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Downstream Surface of Upstream Gates (Both Leafs)

Quant	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			String Anode Perforated Plastic Pipe Protectors							
16	16	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 16, 17, 18 & 19 ***	16.0	32.0	32.0	32.0		I-7 I-9 I-6	K X LM
112	17	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	***	***	***	***			
16	18	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	***	***	***	***		I-6	L
224	19	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	***	***	***	***		I-6 I-7	L K
			Miscellaneous Hardware							
16	20	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
16	21	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	22	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	23	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)						I-8A	
1	24	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	1.0					I-6 I-7	
			Total of Man-Hours for each Labor Classification:	61	128	120	120			
			Labor Rate for each Labor Classification	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$4,575	$7,680	$6,600	$5,400			
			10.0% Contigency for weather delays, etc.:	$458	$768	$660	$540			

$26,680.50 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE USSDSGCP

Upstream Surface of Downstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			HSCCI Anode Assemblies:				
8	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 9 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	$667.66	$5,341.28	I-5 I-7 I-1	I "A-A" "B-B"
40	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode – Connection sealed with factory sealing compound and 2 Plastic Compression Washers.	$301.98	$12,079.20	I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:				
40	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 – 1-1/2" O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 – 1/8" x 1/16" Slots on one face only spaced 90 degrees apart. Includes Items No. 3, 4, 5 & 7 *	$55.00	$2,200.00	I-5B	A
40	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*	*	I-5B	A
40	5	Each	Anode mounting hole Plastic Plug	*	*	I-5B	A
40	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	$5.16	$206.40	I-5B	A
40	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	*	*	I-5B	A
40	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$3,080.00	I-5B	K
			String Anode Metallic Protection and Support Components				
4	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 2&4
4	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R.Q. Note 1
56	11	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L.Q K
8	12	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	13	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	14	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: USSDSGCP

Upstream Surface of Downstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			String Anode Perforated Plastic Pipe Protectors				
8	15	Each	3" Dia. x 40' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
144	16	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$662.40		
8	17	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
288	18	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$3,600.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	19	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	20	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	21	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	22	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	23	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	24	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15%	$5,326.40		
			$40,835.72 TOT. MAT'LS. COST ESTIMATE				

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Downstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			HSCCI Anode Assemblies:							
8	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 7 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 40' Lead on one end.	8.0	24.0	16.0	16.0		I-5 I-7 I-1	I "A-A" "B-B
40	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Plastic Compression Washers. Includes Items No. 2 - 8 *	40.0	120.0	80.0	80.0		I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:							
40	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2" O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart.	*	*	*	*		I-5B	A
40	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*	*	*	*		I-5B	A
40	5	Each	Anode mounting hole Plastic Plug	*	*	*	*		I-5B	A
40	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.	*	*	*	*		I-5B	A
40	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	*	*	*	*		I-5B	A
40	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*		I-5B	K
			String Anode Metallic Protection and Support Components							
4	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates. Includes Items No. 9-14 ** *	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 2&4
4	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	**	**	**	**		I-6 I-1	R,Q, Note 1
56	11	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**		I-6 I-7	L,Q K
8	12	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**		I-6	N
8	13	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**		I-6	N
8	14	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**		I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Downstream Gates (Both Leafs)									Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs.	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Sheet No.	Detail Nos.
			String Anode Perforated Plastic Pipe Protectors							
8	15	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	8.0	24.0	16.0	16.0		I-7 I-9 I-6	K X LM
144	16	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.							
8	17	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.						I-6	L
288	18	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6 I-7	L K
			Miscellaneous Hardware							
8	19	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
8	20	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	21	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	22	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.						I-8A	
1	23	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.						I-6 I-7	
			Total of Man-Hours for each labor classification:	68	204	136	136			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$5,100	$12,240	$7,480	$6,120			
			10.0% Contigency for weather delays, etc.:	$510	$1,224	$748	$612			

$34,034.00 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: OSSOSGCP

Downstream Surface of Downstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			HSCCI Anode Assemblies:				
16	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 5 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 50' Lead on one end.	$370.93	$5,934.88	I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silcon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode – Connection sealed with factory sealing compound and 2 Plastic Compression Washers. *Install 4 each at bottom girder on both gates*	$301.98	$2,415.84	I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:				
8	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 – 1-1/2 " O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 – 1/8" x 1/16" Slots on one face only spaced 90 degrees apart. Includes Items No. 3, 4 & 5 *	$55.00	$440.00	I-5B	A
8	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve	*	*	I-5B	A
8	5	Each	Anode mounting hole Plastic Plug	*	*	I-5B	A
8	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above. Includes Items No.6&7**	$5.16	$41.28	I-5B	A
8	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode	**	**	I-5B	A
8	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			String Anode Metallic Protection and Support Components				
12	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 2&4
8	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
4	11	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*	$195.00	$780.00	I-2	Note 1
16	12	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$140.80	I-6 I-7	L,Q K
16	13	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6	N
16	14	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6	N
16	15	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00	I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Downstream Surface of Downstream Gates (Both Leafs)									Dwg. Reference	
Quant	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Sheet No.	Detail Nos.
			HSCCI Anode Assemblies:							
16	1	Strings	2" O.D. x 1.5" I.D. x 9" Long, Hi-Silicon Chromium Cast Iron Anode Strings assembled with Nose Cones per C.O.E. Dwgs, Detail "I" on Sheet 1-5, 5 Segments/String, Segments located 4'6" Center to Center (Note: Approx. C-C Spacing is approximate only, assemble to center one segment each within chambers at or below Upper Pool Elevation) assembled on #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation with 50' Lead on one end.	8.0	24.0	16.0	16.0		I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	6" Dia. x 3" Deep Type "A" Hi-Silicon Chromium Cast Iron Button Anode factory assembled per C.O.E. Drawing, Detail "D" on Sheet 1-5 (also I-5A), with 60' of #8 AWG, Stranded Copper Cable with Type RHH/RHW/USE Hypalon Insulation connected to Back of Anode - Connection sealed with factory sealing compound and 2 Plastic Compression Washers. *Install 4 each at bottom girder on both gates*	40.0	120.0	80.0	80.0		I-5 & I-5B	D D
			HSCCI Button Anode Mounting Components:							
8	3	Each	3/4" x 3-1/2" Long Hex Head Steel Bolt complete with Nut and 2 - 1-1/2" O.D. Std. Steel Washers. Bolt equipped with "T" shaped 3/16" Dia. Epoxy Filling Port. Anode side Washer to have 4 - 1/8" x 1/16" Slots on one face only spaced 90 degrees apart.						I-5B	A
8	4	Each	3/4" I.D. x 3" Long Flanged Nylon Insulating Sleeve						I-5B	A
8	5	Each	Anode mounting hole Plastic Plug						I-5B	A
8	6	Each	Type "CGB" Pressure Insulating 3/4" Threaded Connector suitable for #8 AWG Insulated Wire specified above.						I-5B	A
8	7	Each	1/8" Thick x 1" I.D. x 8" O.D. Neoprene Anode Insulating Gasket complete with sufficient Epoxy Cement to adhere gasket to steel plate and anode						I-5B	A
8	8	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.						I-5B	K
			String Anode Metallic Protection and Support Components:							
12	9	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 2&4
8	10	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*						I-6 I-1	R,Q, Note 1
4	11	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*							
16	12	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe						I-6 I-7	L,Q K
16	13	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.						I-6	N
16	14	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.						I-6	N
16	15	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps						I-6	N

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: DSSDSGCP FILE: DSSUSGCP

Downstream Surface of Downstream Gates (Both Leafs)									Dwg. Reference	
Quant	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs.	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Sheet No.	Detail Nos.
			String Anode Perforated Plastic Pipe Protectors							
16	16	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	8.0	24.0	16.0	16.0		I-7 I-9 I-6	K X LM
112	17	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.							
16	18	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.						I-6	L
224	19	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6 I-7	L K
			Miscellaneous Hardware							
16	20	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
16	21	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	22	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	23	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)						I-8A	
1	24	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	1.0					I-6 I-7	
			Total of Man-Hours for each Labor Classification:	69	204	136	136			
			Labor Rate for each Labor Classification	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$5,175	$12,240	$7,480	$6,120			
	25		**10.0% Contigency for weather delays, etc.:**	$518	$1,224	$748	$612			

$34,116.50 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Ceramic Coated Titanium Anode Assemblies				
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 9 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	$872.98	$6,983.84	I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$16,073.60	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
32	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$2,464.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 3&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
56	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$257.60		
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
112	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$1,400.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$5,327.86		

$40,846.94 TOT. MAT'LS. COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

			Upstream Surface of Upstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies							
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 9 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	6.0	20.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B"
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Waterproof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	16.0	48.0	32.0	32.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
32	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	**	**	**	**		I-5B	K
			Rod Anode Metallic Protection and Support Components	4.0	12.0	8.0	8.0			
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*						I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	***	***	***	***		I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	***	***	***	***		I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	***	***	***	***		I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	***	***	***	***		I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	***	***	***	***		I-6	N
			String Anode Perforated Plastic Pipe Protectors	8.0	24.0	16.0	16.0			
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****						I-7 I-9 I-6	K X L,M
56	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	****	****	****	****			
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	****	****	****	****		I-6	L
112	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	****	****	****	****		I-6 I-7	L K
			Miscellaneous Hardware	8.0	24.0	16.0	16.0			
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. KS-25 for suspending string anodes. Includes Items No.19, 20, 21, 22 & 23*****						I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	*****	*****	*****	*****		I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	*****	*****	*****	*****			
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	*****	*****	*****	*****		I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.	*****	*****	*****	*****		I-6 I-7	
			Total of Man-Hours for each labor classification:	42	128	84	84			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,150	$7,680	$4,620	$3,780			
1	19		**10.0% Contigency for weather delays, etc.:**	$315	$768	$462	$378			

$21,153.00 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE D85USOCX

Upstream Surface of Upstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies				
16	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 9 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	$872.98	$13,967.68	I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$4,018.40	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 2&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
16	6	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$140.80	I-6 I-7	L,Q K
16	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6	N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
16	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$3,152.00	I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$515.20		
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$244.80	I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$2,800.00	I-6 I-7	L K
			Miscellaneous Hardware				
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$72.00	I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$61.76	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$4,942.82		

$37,894.94 TOT. MAT'LS. COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE D85U BOCX

Upstream Surface of Upstream Gates (Both Leafs)									Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies							
16	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 9 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	12.0	24.0	24.0	24.0		I-5 I-7 I-1	I "A-A" "B-B"
8	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Waterproof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	4.0	8.0	8.0	8.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*		I-5B	K
			Rod Anode Metallic Protection and Support Components	12.0	24.0	24.0	24.0			
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*						I-7 I-6 I-1	K L Notes 2&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	**	**	**	**		I-6 I-1	R,Q, Note 1
16	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**		I-6 I-7	L,Q K
16	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**		I-6	N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**		I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**		I-6	N
			String Anode Perforated Plastic Pipe Protectors	16.0	32.0	32.0	32.0			
16	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****						I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	***	***	***	***			
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	***	***	***	***		I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	***	***	***	***		I-6 I-7	L K
			Miscellaneous Hardware	8.0	24.0	16.0	16.0			
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. KS-25 for suspending string anodes. Includes Items No.19, 20, 21, 22 & 23*****						I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.	1.0					I-6 I-7	
			Total of Man-Hours for each labor classification:	53	112	104	104			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,975	$6,720	$5,720	$4,680			
1	19		**10.0% Contigency for weather delays, etc.:**	$398	$672	$572	$468			

$23,204.50 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: US500.DCX

Upstream Surface of Upstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies				
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 11 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	$1,054.21	$8,433.68	I-5 I-7 I-1	I "A-A" "B-B
40	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$20,092.00	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
40	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$3,080.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
144	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$662.40		
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
288	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$3,600.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$6,631.22		
					$50,839.34 TOT. MAT'LS. COST ESTIMATE		

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)									Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies							
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 11 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	6.0	18.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B"
40	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	20.0	60.0	40.0	40.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
40	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*		I-5B	K
			Rod Anode Metallic Protection and Support Components	4.0	12.0	8.0	8.0			
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*						I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	**	**	**	**		I-6 I-1	R,Q, Note 1
6	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**		I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**		I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**		I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**		I-6	N
			String Anode Perforated Plastic Pipe Protectors	8.0	24.0	16.0	16.0			
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****						I-7 I-9 I-6	K X L,M
144	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.							
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.						I-6	L
288	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6 I-7	L K
			Miscellaneous Hardware	8.0	24.0	16.0	16.0			
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. KS-25 for sus-pending string anodes. Includes Items No.19, 20, 21, 22 & 23*****						I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.						I-6 I-7	
			Total of Man-Hours for each labor classification:	46	138	92	92			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,450	$8,280	$5,060	$4,140			
1	19		**10.0% Contigency for weather delays, etc.:**	$345	$828	$506	$414			
			$23,023.00 TOTAL LABOR COST ESTIMATE							

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Ceramic Coated Titanium Anode Assemblies				
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 6 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	$601.13	$4,809.04	I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$16,073.60	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 3&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long – *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
4	6	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*	$195.00	$780.00	I-6 I-7	L,Q K
16	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6	N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/16" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
16	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$3,152.00	I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$515.20		
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$244.80	I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$2,800.00	I-6 I-7	L K
			Miscellaneous Hardware				
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$72.00	I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$61.76	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$5,473.18		
			$41,961.06 TOT. MAT'LS. COST ESTIMATE				

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE 0S809OCX

Upstream Surface of Upstream Gates (Both Leafs)									Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies							
8	1	Assemblies	1/8" Diameter Expand-a-Rod Anode Assemblies consisting of 6 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	6.0	18.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B"
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-a-Node Part No. LSA, complete with Cer-a-Node Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	20.0	60.0	40.0	40.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.						I-5B	K
			Rod Anode Metallic Protection and Support Components							
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 3&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long – *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*						I-6 I-1	R,Q, Note 1
4	6	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*						I-6	L,Q
16	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.						I-7 I-6	K N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/16" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.						I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps						I-6	N
			String Anode Perforated Plastic Pipe Protectors							
16	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****	8.0	24.0	16.0	16.0		I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.							
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.						I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6 I-7	L K
			Miscellaneous Hardware							
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. KS-25 for sus-pending string anodes. Includes Items No. 19, 20, 21, 22 & 23*****	8.0	24.0	16.0	16.0		I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.	1.0					I-6 I-7	
			Total of Man-Hours for each labor classification:	47	138	92	92			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,525	$8,280	$5,060	$4,140			
1	19		**10.0% Contigency for weather delays, etc.:**	$353	$828	$506	$414			
			$23,105.50 TOTAL LABOR COST ESTIMATE							

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES

PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)				
8	1	String	1/8" Diameter Continuous Rod Anode Assemblies consisting of 36' long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factory Completed Water Proof Connection to 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached, Materials Protection Company Part No. MPPRA-125-36-STD-40/14	$386.17	$3,089.36	I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA, complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$16,073.60	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
32	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$2,464.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
56	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$257.60		
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
112	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$1,400.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$4,743.69		

$36,368.29 TOT. MAT'LS. COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Upstream Surface of Upstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Foreman Man-Hrs.	Electrician Man-Hrs.	Welder Man-Hrs.	Laborer Man-Hrs.	Misc. Man-Hrs.	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)							
8	1	String	1/8" Diameter Continuous Rod Anode Assemblies consisting of 36' long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factory Completed Water Proof Connection to 40' of #14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached, Materials Protection Company Part No. MPPRA-125-36-STD-40/14	6.0	20.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B"
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA, complete with Cer-Anode Part No. LSA-12-5-CC-60 Waterproof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	16.0	48.0	32.0	32.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
32	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	**	**	**	**		I-5B	K
			Rod Anode Metallic Protection and Support Components							
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	***	***	***	***		I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	***	***	***	***		I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	***	***	***	***		I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	***	***	***	***		I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	***	***	***	***		I-6	N
			String Anode Perforated Plastic Pipe Protectors							
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets. Includes Items No. 15, 16, 17 & 18 ****	8.0	24.0	16.0	16.0		I-7 I-9 I-6	K X L,M
56	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	****	****	****	****			
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	****	****	****	****		I-6	L
112	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	****	****	****	****		I-6 I-7	L K
			Miscellaneous Hardware							
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. KS-25 for suspending string anodes. Includes Items No.19, 20, 21, 22 & 23*****	8.0	24.0	16.0	16.0		I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	*****	*****	*****	*****		I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	*****	*****	*****	*****			
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	*****	*****	*****	*****		I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case.	*****	*****	*****	*****		I-6 I-7	
			Total of Man-Hours for each labor classification:	42	128	84	84			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,150	$7,680	$4,620	$3,780			
1	19		**10.0% Contigency for weather delays, etc.:**	$315	$768	$462	$378			

$21,153.00 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Downstream Surface of Upstream Gates (Both Leafs)				
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)				
16	1	Strings	1/8" Diameter Continuous Anode Assemblies consisting of 36' Long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factor Completed Water Proof Connection to 40' of # 14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire Attached, Materials Protection Company Part No. MPPRA-125-36-STD-40/14	$386.17	$6,178.72	I-5 I-7 I-1	I "A-A" "B-B
8	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$4,018.40	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 2&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
16	6	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$140.80	I-6 I-7	L,Q K
16	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6	N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00	I-6	N
			String Anode Perforated Plastic Pipe Protectors				
16	10	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$3,152.00	I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$515.20		
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$244.80	I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$2,800.00	I-6 I-7	L K
			Miscellaneous Hardware				
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$72.00	I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$61.76	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$3,774		
					$28,937.63 TOT. MAT'LS. COST ESTIMATE		

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE DSSUSGCZ

Downstream Surface of Upstream Gates (Both Leafs)									Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)							
16	1	Strings	1/8" Diameter Continuous Anode Assemblies consisting of 36' Long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factor Completed Water Proof Connection to 40' of # 14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire Attached. Materials Protection Company Part No. MPPRA-125-36-STD-40/14	12.0	24.0	24.0	24.0		I-5 I-7 I-1	I "A-A" "B-B"
8	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	4.0	8.0	8.0	8.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*		I-5B	K
			Rod Anode Metallic Protection and Support Components							
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	12.0	24.0	24.0	24.0		I-7 I-6 I-1	K L Notes 3&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	**	**	**	**		I-6 I-1	R,Q, Note 1
16	6	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**		I-6 I-7	L,Q K
16	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**		I-6	N
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**		I-6	N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**		I-6	N
			String Anode Perforated Plastic Pipe Protectors							
16	10	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	16.0	32.0	32.0	32.0		I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	***	***	***	***			
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	***	***	***	***		I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	***	***	***	***		I-6 I-7	L K
			Miscellaneous Hardware							
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	1.0					I-6 I-7	
			Total of Man-Hours for each Labor Classification:	53	112	104	104			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,975	$6,720	$5,720	$4,680			
1	19		**10.0% Contigency for weather delays, etc:**	$398	$672	$572	$468			
			$23,204.50 TOTAL LABOR COST ESTIMATE							

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE U880 90C2

Upstream Surface of Downstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)				
8	1	Strings	1/8" Diameter Continuous Rod Anode Assemblies consisting of 44' long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factory Completed Water Proof Connection to 40' of # 14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached, Material Protection Company Part No. MPPRA-125-44-STD-40/14	$474.85	$3,798.80	I-5 I-7 I-1	I "A-A" "B-B
40	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$20,092.00	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
40	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$3,080.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long – *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	$37.01	$148.04	I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long – *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	$297.06	$1,188.24	I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" – Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	$8.80	$492.80	I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$289.84	I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$73.84	I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$92.00	I-6	N
			Rod Anode Perforated Plastic Pipe Protectors				
8	10	Each	3" Dia. x 30' Long Schedule 80 PVC Pipe perforated with 1-1/2" Dia Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$1,576.00	I-7 I-9 I-6	K X L,M
144	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$662.40		
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$15.30	$122.40	I-6	L
288	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$3,600.00	I-6 I-7	L K
			Miscellaneous Hardware				
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$36.00	I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$30.88	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$5,935.99		
			$45,509.23 TOT. MAT'LS. COST ESTIMATE				

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE U880EOCZ

Upstream Surface of Downstream Gates (Both Leafs)

Quant.	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs.	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Dwg. Reference Sheet No.	Dwg. Reference Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)							
8	1	Strings	1/8" Diameter Continuous Rod Anode Assemblies consisting of 44' long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factory Completed Water Proof Connection to 40' of # 14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached, Material Protection Company Part No. MPPRA-125-44-STD-40/14	6.0	18.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B
40	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	20.0	60.0	40.0	40.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
40	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	*	*	*	*		I-5B	K
			Rod Anode Metallic Protection and Support Components							
4	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 10' Long - *To be installed behind perforated plastic pipe protectors for Anodes 1S2 & 2S2 only on both gates.*	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 2&4
4	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 16' Long - *To be installed in front of Anodes 1S2 & 2S2 only on both gates*	**	**	**	**		I-6 I-1	R,Q, Note 1
56	6	Each	4" Long Steel Pipe "Collars" - Cut from Std. 4" Dia. (4-1/2" O.D.) Steel Pipe	**	**	**	**		I-6 I-7	L,Q K
8	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	**	**	**	**		I-6	N
8	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	**	**	**	**		I-6	N
8	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	**	**	**	**		I-6	N
			Rod Anode Perforated Plastic Pipe Protectors							
8	10	Each	3" Dia. x 40' Long Schedule 80 PVC Pipe perforated with 1-1/2" Di Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	8.0	24.0	16.0	16.0		I-7 I-9 I-6	K X L,M
144	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.							
8	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.						I-6	L
288	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6 I-7	L K
			Miscellaneous Hardware							
8	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
8	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP.						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for all four (4) gate leaves.)						I-6 I-7	
			Total of Man-Hours for each labor classification:	46	138	92	92			
			Labor Rate for each Labor Classification:	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,450	$8,280	$5,060	$4,140			
1	19		**10.0% Contigency for weather delays, etc.:**	$345	$828	$506	$414			

$23,023.00 TOTAL LABOR COST ESTIMATE

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

Downstream Surface of Downstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Unit Cost	Extended Cost	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)				
8	1	Strings	1/8" Diameter Continuous Rod Anode Assemblies consisting of 24' Long x 1/8" Dia. TIR-2000 Ceramic Standard Weight Coated Titanium Rod with Factory Completed Water Proof Connection to Waterproof Connector attached to top end of assembly to 50' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached, Materials Protection Company Part No. MPPRA-125-24-STD-50/14	$354.00	$2,832.00	I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Waterproof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	$502.30	$16,073.60	I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:				
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.	$77.00	$616.00	I-5B	K
			Rod Anode Metallic Protection and Support Components				
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	$37.01	$444.12	I-7 I-6 I-1	K L Notes 2&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*	$214.75	$1,718.00	I-6 I-1	R,Q, Note 1
4	6	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*	$195.00	$780.00	I-2	Note 1
16	7	Each	5" Long Steel Pipe "Anchorages" - Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.	$36.23	$579.68	I-6 I-7	L,Q K
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.	$9.23	$147.68	I-6 I-6	N N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps	$11.50	$184.00		
			String Anode Perforated Plastic Pipe Protectors				
16	10	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	$197.00	$3,152.00	I-7 I-9 I-6	K X L,M
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.	$4.60	$515.20		
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.	$4.60	$73.60	I-6	L
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive	$12.50	$2,800.00	I-6 I-7	L K
			Miscellaneous Hardware				
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	$4.50	$72.00	I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.	$3.86	$61.76	I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.	$1,000.00	$1,000.00		
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)	$929.00	$929.00	I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	$2,361.00	$2,361.00	I-6 I-7	
1	19	Lot	Contigency for Freight, Breakage, Spares, Lost Components, etc.	15.0%	$5,150.95		
					$39,490.59 TOT. MAT'LS. COST ESTIMATE		

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE
IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM
FOR PIKE ISLAND LOCK & DAM MITER GATES
PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: DS10 80CZ

			Downstream Surface of Downstream Gates (Both Leafs)						Dwg. Reference	
Quant.	Item No.	Unit	Description	Foreman Man-Hrs	Electrician Man-Hrs.	Welder Man-Hrs	Laborer Man-Hrs	Misc. Man-Hrs	Sheet No.	Detail Nos.
			Ceramic Coated Titanium Anode Assemblies (Alternate #1)							
8	1	Strings	1/8" Diameter Expand-a-Rod Anode Assemblies Consisting of 6 Cer-Anode Part No. EAR-4 Anode Rods, each 4 Ft. Long, Screw Coupled Together with Cer-Anode Part No. EAR-ICC-40 Waterproof Connector attached to top end of assembly with 40' of # 14 Type RHH/RHW/USE Insulated Stranded Copper Lead Wire attached.	6.0	18.0	12.0	12.0		I-5 I-7 I-1	I "A-A" "B-B
32	2	Assemblies	12" Diameter Overall Disk Anode Assembly with 5" Diameter Ceramic Coated Anode Assembly, Cer-Anode Part No. LSA complete with Cer-Anode Part No. LSA-12-5-CC-60 Water-proof submersibly replaceable Connector with 60' of #14 RHH/RHW/USE Insulated Stranded Copper Lead Wire attached Plastic Compression Washers.	20.0	60.0	40.0	40.0		I-5 & I-5B	D D
			Ceramic Disk Anode Mounting Components:							
8	3	Each	Button Anode Cabling Protection Assembly consisting of 8" Dia. x Approx. 8" Long Schedule 40 Pipe Threaded on one end and fitted with pipe cap and 1/2" thread-o-let welded to one side for conduit entrance.						I-5B	K
			Rod Anode Metallic Protection and Support Components							
12	4	Each	3-1/2" x 3-1/2" x 3/8" Angle Iron, 13' Long *To be installed behind perforated plastic pipe protectors for Anodes 1S4, 1S5, 1S6, 2S4, 2S5 & 2S6 only on both gates*	4.0	12.0	8.0	8.0		I-7 I-6 I-1	K L Notes 2&4
8	5	Each	6" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S5, 1S6, 2S5 & 2S6 only on both gates*						I-6 I-1	R,Q, Note 1
4	6	Each	4" Wide x 2-1/8" Deep x 5/16" Thick Steel "U" Channel, 11' Long *To be installed in front of perforated plastic pipe protectors for Anodes 1S4 & 2S4 only on both gates*							
16	7	Each	5" Long Steel Pipe "Anchorages" – Cut from Std. 2-1/2" Dia. (2-7/8" O.D.) Steel Pipe.						I-6 I-7	L,Q K
16	8	Each	5/16" x 4" Anchorage Bolt with 1 Washer and 5/15" I.D. Ring Tounge "T&B" Connector with 9" of #8 AWG Strand Copper Insulated Grounding Cable attached. Also include 2 Plastic Caps for covering Bolt Head and Nut.						I-6 I-6	N N
16	9	Each	Pints "Epoxy" for filling Anchorage and Bolt Caps							
			String Anode Perforated Plastic Pipe Protectors						I-6	N
16	10	Each	30' of 3" Dia. Schedule 80 PVC Pipe perforated with 1-1/2" Dia. Holes on 2" Centers on 180 Degrees of Pipe Surface. See Detail Sheets.	8.0	24.0	16.0	16.0		I-7 I-9	K X
112	11	Each	20" Long x 3" Dia. Schedule 80 PVC "non-perforated" Pipe for penetrations thru girders.						I-6	L,M
16	12	Each	3-1/2" Schedule 80 PVC Plastic Pipe Adapter for use at upper termination of 3" Perforated Pipe run.							
224	13	Each	Schedule 80 PVC Pipe Coupling complete with solvent welding adhesive						I-6	L
			Miscellaneous Hardware						I-6 I-7	L K
16	14	Each	Joslyn Cat. No. J-1944 Clevis with Insulator No. J-99 for suspending string anodes.	8.0	24.0	16.0	16.0		I-5	F
16	15	Each	3" x 3" x 3" Long Angle Iron Brackets for clevis string anode support.						I-5	F
1	16	Lot	Conduit, Condulets, Watertight Conduit Girder Pentration Fittings, "U" Bolt Conduit Clamps, etc.							
1	17	Each	44 Terminal (with 0.01 ohm Shunts) Anode Terminal Box with all Fittings, Hoffman Type 4X Fiberglass Case with S.S. fittings, Cat. No. A-30H2410GQLRP. (NOTE: One (1) each is required for each gate leaf or a total of four (4) are required for the project.)						I-8A	
1	18	Each	Dual Output Circuit Cathodic Protection Rectifier with D.C. output capacity per Circuit of 10 Amperes at 24 Volts, manual tap adjustment of output voltage in 20 steps for each circuit, in "Ice Cream Cart" Hot Dip Galvanized Case. (NOTE: This rectifier will actually feed both the upstream and downstream surfaces of one leaf only. There will be a total of four (4) rectifiers for the project.)	1.0					I-6 I-7	
			Total of Man-Hours for each Labor Classification:	47	138	92	92			
			Labor Rate for each Labor Classification	$75	$60	$55	$45	$50		
			Base Labor Cost Estimate for each Labor Classification:	$3,525	$8,280	$5,060	$4,140			
1	19		**10.0% Contigency for weather delays, etc.:**	$353	$828	$506	$414			
			$23,105.50 TOTAL LABOR COST ESTIMATE							

U.S. ARMY C.E.R.L. DETAILED COST ESTIMATE

IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

FOR PIKE ISLAND LOCK & DAM MITER GATES

PREPARED BY: Corrpro Companies, Inc. PRINCIPAL ENGINEER: James B. Bushman

FILE: L&DSUM

SUMMARY OF CATHODIC PROTECTION SYSTEM COSTS FOR EACH ALTERNATIVE

	HI-SI C.I. OPTION		CERAMIC OPTION		CERAMIC ALTERNATE #1 OPTION	
GATE SURFACE	LABOR	MATERIALS	LABOR	MATERIALS	LABOR	MATERIALS
Upstream Surface of Upstream Gate	30,030.00	32,435.11	21,153.00	40,846.94	21,153.00	36,368.29
Downstream Surface of Upstream Gate	26,680.50	30,994.57	23,204.50	37,894.94	23,204.50	28,937.63
Upstream Surface of Downstream Gate	34,034.00	40,835.72	23,023.00	50,839.34	23,023.00	45,509.23
Downstream Surface of Downstream Gate	34,116.50	26,917.87	23,105.50	41,961.06	23,105.50	39,490.59
TOTAL INSTALLED COST FOR EACH ALTERNATIVE		$256,044.27		$262,028.28		$240,791.74

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